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**GOVERNMENT OF INDIA
CENTRAL WATERWAYS IRRIGATION
AND NAVIGATION COMMISSION**

**MAHANADI VALLEY DEVELOPMENT
HIRAKUD DAM PROJECT**

VOLUME I—REPORT

JUNE 1947

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**PRINTED IN INDIA BY THE MANAGER
GOVERNMENT OF INDIA PRESS SIMLA 1947**



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UNIFIED DEVELOPMENT OF THE MAHANADI VALLEY HIRAKUD DAM PROJECT

SUMMARY AND RECOMMENDATIONS.

GENERAL.

At a Conference held on 8th November 1945 at Cuttack under the Chairmanship of the Hon'ble Dr. B. R. Ambedkar, Member for Labour in the Government of India, the representatives of Orissa, Orissa States and Central Provinces, unanimously agreed that the potentialities of the Mahanadi river for unified multiple-purpose development, *e.g.*, for flood control, irrigation, navigation and hydro-electric power, should be thoroughly and expeditiously investigated. The surveys and investigations in this connection were accordingly undertaken by the Central Waterways, Irrigation and Navigation Commission.

This Project Report contains an outline of these surveys and investigations, sets out the many problems of Orissa and indicates the magnitude of her natural resources and the immense possibilities for the conservation and utilisation of these resources for the benefit of the common man and the nation.

RESOURCES OF ORISSA.

Orissa which comprises the Province of Orissa and the Orissa States, covers an area of 50,349 sq. miles, an area as big as that of England. It has a population of nearly 12 millions which is five times that of the Tennessee Valley in U.S.A.

This region contains vast areas of agricultural land and forests. It is traversed by three major rivers, the Mahanadi, the Brahmini and the Baitarani, and two minor ones the Burablong and the Subarnrekha. The Mahanadi, the biggest river of Orissa, carries annually 74 million acre feet of water, which is only slightly less than the volume of water carried by the Indus in the Punjab, but is very much in excess of that carried by the Tennessee river in U. S. A.

A look at the mineral map of the region (Plate II) will give an idea of the great potential mineral wealth of Orissa and the neighbouring areas. There are large deposits of coal, iron, bauxite, manganese, graphite, chromite, mica, limestone, etc.

Nature has thus endowed this region with great resources in land, water, minerals and man power.

POTENTIALITIES FOR DEVELOPMENT.

If even a part of these immense resources can be exploited through integrated multiple purpose development, Orissa will rise to unprecedented heights of prosperity and power.

The waters of the Mahanadi, if fully harnessed can, beside affording complete flood protection to the delta areas, irrigate over 20 million acres of land (if that much land is available), generate four million k.w. of power (which is twice the total power developed at the 26 dams of the T. V. A.), provide a navigable waterway with a minimum draught of 9 to 10 feet, extending 380 miles from the border of Central Provinces to the sea, make it possible to develop a deep sea port for Orissa at Chandbali or Dhamra capable of handling nearly 6 million tons of traffic (the annual traffic handled by the Port of Calcutta in the pre-war years was nearly 10 million tons), create extensive lakes to serve as a sea-plane base and afford facilities for fish culture, recreation, etc.

PRESENT POSITION.

Navigation on the Mahanadi, which was fairly considerable in the past, has almost disappeared mainly as a result of a mistaken railway policy. The manpower of the Province, which is admittedly intelligent and industrious, is being largely wasted for want of opportunity and full time employment. The life giving waters of its rivers, which could provide irrigation to raise more crops and cheap hydro-power to turn the wheels of industry and thus raise the standard of living of the common man, are at present running to waste causing untold damage and destruction by floods in their passage to the sea. Less than 5 per cent. of this water is at present being put to beneficial use for purposes of irrigation. The mineral wealth of the area is lying unexploited and unexplored ; there are no industries worth the name.

Thus inspite of the tremendous wealth in land, water, minerals and manpower, Orissa continues to be a backward province, suffering from chronic poverty and low income diseases and haunted by the two spectres of flood and drought:

UNIFIED DEVELOPMENT OF THE MAHANADI VALLEY.

The scheme for the unified development of the Mahanadi Valley is designed to put a stop to this colossal waste of manpower and natural resources and to control, conserve and utilise the waters of the Mahanadi river for purposes of irrigation, hydro-power generation, navigation, flood control and other facilities such as fish culture, malaria control, soil conservation, recreation etc., with a view to raising the standard of living of the common man by banishing famine, malnutrition and disease and extending to him the necessities and amenities of modern life. This scheme will comprise three units, namely the Hirakud Dam Project, the Tikarpara Dam Project and the Naraj Dam Project, each one with its own canal system and hydro electric power installations. These three units will be individually capable of independent development, irrespective of whether the other two are constructed or not, and of forming an integral part of the basin-wide plan.

The best overall results will obviously be obtained if and when all the three projects have been completed. But this overall development will take time before it can be implemented in full. It will involve the submergence of large areas of land and major problems of resettlement of the dispossessed people. Fortunately, however, each component can independently play a most vital role in the development of the region. As a first step, therefore, it is proposed to make a start with the construction of the Hirakud Dam Project.

HIRAKUD DAM PROJECT.

General.

Of the three units of the basin-wide plan, the Hirakud Dam Project lies uppermost on the Mahanadi river and is the simplest in respect of physical features, territorial considerations, and design and construction requirements. It is also one which would yield the quickest results. It will be financially self-supporting. The Hirakud Dam Project which forms the subject matter of this report, comprises the construction of a dam across the Mahanadi about 9 miles upstream of the town of Sambalpur, gravity and lift canals on either side and two hydro-electric installations.

Dam and reservoir.

The dam will be nearly three miles in length across the main channel with 17 miles length of low dykes on the two side. The maximum height of the dam above the deepest river bed will be 150 ft. The reservoir formed by the dam will rise to R.L. 625.00 and submerge an area of 135,000 acres, of which nearly 70,000 acres will be cultivated land. The reservoir will have a gross storage capacity of 5.3 million acre feet of which 1.2 m.a. ft. will be dead storage to serve as silt reserve and to provide head for generating power. The remaining 4.1 m.a. ft. will be live or usable storage for use of irrigation, hydro-electric power and flood control and for improving navigation facilities.

The storage of water and its use as envisaged in the Project will in no way adversely affect the water rights of the upper or lower riparian States including Central Provinces. The lower States will be beneficially affected, in that excessive floods will be controlled and minimum dry weather supplies materially improved.

Irrigation.

The project provides for the irrigation of 1,094,953 acres of land out of which 880,000 acres will be in the Sambalpur District of Orissa, and the rest in Sonepur State. The Irrigation of 619,035 acres will be by flow and of 475,918 acres by lift. Two canals will take off from the reservoir on the right bank, separately, for flow and lift irrigation. Similarly two canals will take off on the left. A small lift channel will also take off from the north of the reservoir for irrigation of jungle areas there. A gravity canal will take off from the subsidiary reservoir on the right bank for irrigation of areas south of this canal. Electric power will be used for pumping water into the lift canals. The full supply capacity of all these canals will be 8,800 cusecs.

Irrigation in the delta.

Besides the 1,094,953 acres of land in Sambalpur District and Sonepur State, which will receive irrigation from the Hirakud Dam, the regulated supplies from the latter (ranging between 8,800 to 14,000 cusecs during the dry months against the present minimum of about 1,000 cusecs at Naraj) will provide protective irrigation to existing irrigated areas in the delta during critical periods of short supply, and enable perennial irrigation to be extended to additional large areas in the delta, which cannot be brought under irrigation at present due to the likelihood of their getting submerged during floods, but which will become available for irrigation as a result of flood protection, which will be afforded by the construction of the Hirakud Dam. This additional irrigation may cover a very large area.

A thorough enquiry into the existing irrigation in the delta, the reasons for its being unproductive and the possibilities for improvement and extension seems to be urgently called for.

Power.

Power will be generated at the Hirakud Dam in two parts; one at the main dam at Hirakud to utilise the fall created by the construction of the dam; and the second at the subsidiary dam forming the balancing reservoir at the end of the power channel from the upper power house, to utilise the steep slope in the river below Hirakud. The operating heads at the two power houses will be about equal (85 ft.). The total installed capacity at the two power houses will be 350,000 k.w., with six units of 25,000 k.w. each installed at the upper power station and eight units of 25,000 k.w. each at the lower power station. The installation of units will be done by stages to suit the development of load.

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The system will be capable of meeting a maximum demand of 300,000 k.w. making available about 1,612 million k.w. hours annually. In a year of extremely low supply 5.4 per cent. of the total generation may have to be done from supplemental steam electric station. In normal years the entire output will be from hydro-electric generation.

It is proposed to connect the Hirakud Power stations by means of 132 kv. transmission lines to Cuttack and Jamshedpur and later on to Machkund Power station. For lift irrigation, 33 kv. lines will be taken to the pumping stations. Ultimately the Hirakud Power station will be linked up in grid to the proposed power stations at Tikarpara, Naraj, Kosi, Tista, Damodar, Rihand and Nagpur.

The rate structure for hydro-electric power will follow the generally accepted principles. The rates will be governed by the size of the load, load factor, the distance of transmission and the nature of the industry concerned. The rate for pumping has been kept very low (i.e. Rs. 20 per k.w. year of peak demand) and involves an element of subsidy in the interest of growing more food. The rates for industrial and other loads will progressively drop from Rs. 160 for an installed capacity of 100,000 k.w. to Rs. 100 for an installed capacity of 350,000 k.w., the average rates per unit at the consumers end being 0.573 and 0.358 of an anna in the two cases, respectively. Special concession rates will apply to rural consumers.

Plans for the industrialisation of undeveloped countries invariably begin with the production of electrical power. This was true in Soviet Russia where even as recently as 1935 the total electric energy per person was only 141 kilowatt hours. Electric power is the lifeblood of modern warfare. Take aluminium, for example, which is required for the production of air craft. Aluminium is mostly the product of electric power.

If cheap power can be made available, there seems to be no limit to the opportunities for the industrial development of Orissa with its large deposits of key minerals within easy reach and a population of nearly 12 million. With the growth of industries, the demand for power will not be limited to the 300,000 k.w. to be generated at the Hirakud Dam, but may rise to 3 million k.w. or more. Fortunately the additional power, if required, will be available from the Tikarpara dam with its power potential of 2-1/2 million k.w., and the Naraj Dam with its power potential of 1 million k.w.

Flood control.

Part of the capacity of the reservoir at Hirakud will be reserved for flood regulation so that the peak flood supplies can be stored in the reservoir and gradually released later on in such a way that the limiting flood gauge of 90.0 at Naraj is never exceeded and the safe flood gauge of 89.0 is exceeded only in extraordinary floods and that for a few days only. In this way, adequate flood protection will be assured to the Delta area, and considerable relief to Sambalpur town and riverain areas in States lower down.

Navigation.

In its existing state, the Mahanadi river does not afford much facilities for navigation. In the monsoon months navigation may be dangerous due to high floods. During the rest of the year the current is sluggish and the discharge small; in bad years it may be as low as 900 cusecs. After the construction of the dam, there will be great improvement in the regime of the river as the regulated releases of water from the reservoir to the river downstream of the

dam, will range between 8,800 and 14,000 cusecs during dry season. With a certain amount of blasting of the jutting rocks in the river bed and other conservancy measures the navigability of the river can be very materially improved thus making it possible for 600 to 800 ton tows to ply from the sea to Dalab and hence via the power-cum-navigation canal through a series of locks into the reservoir and on to the Central Provinces. There are possibilities of developing inland ports at Cuttack, Dasapur Sopurothpur, Kantilo, Nuapara, Sama, Tikarpara, Kaintragharh, Bandh, Baunsum, Sonepur and Binka ; and a major deep sea port at Chandbali or Lhamra. The full development of these facilities will, however, be possible only after the construction of one of the two lower dams at Tikarpara or Naraj.

The Mahanadi, as a navigable waterway, will open great possibilities for the cheap transport of agricultural and industrial produce of the valley for local distribution and export abroad.

The 11 miles long power cum navigation canal with its water depth of 17 ft to 20 ft. will afford an ideal place for navigational research.

Malaria control.

Malaria control will form an essential feature of the project.

Miscellaneous facilities.

Besides the purposes mentioned above, the Hirakud Dam Project will provide facilities for soil conservation, silt control, fish culture and recreation.

Sea-plane base.

The Hirakud reservoir will provide a suitable sea ~~plane plane~~ base at a strategic location.

SUBMERGED AREA AND PROBLEM OF RESETTLEMENT.

The Hirakud reservoir will submerge an area of 135,000 acres of which 70,000 acres is cultivated land. There is considerable agitation among the people whose lands will be submerged, and who will thus be dislocated. This agitation is natural and not unusual. Similar agitation has been experienced at the major barrages in the Punjab, the Krishnarajasagar in Mysore and at the various dams of the Tennessee Valley in U.S.A. It must, however, be recognised that no major project for the control, conservation and utilisation of water can be constructed without submerging some valuable property and considerable areas of culturable and other land. Further the schemes of development for the greater good of the community cannot be held up or abandoned in the interest of a group of individuals. Such schemes undoubtedly involve some hardship to the people whose land and property are submerged. But if the compensation is adequate and arrangements for resettlement satisfactory, the re-location of such people should not involve any material sacrifice on their part beyond some inconvenience and hardship on sentimental grounds.

In any case, the interest of the community and the country must take priority over the sentiments, convenience and interests of the few. If a project is proved to be in the greater good of the community and the country, it must be implemented inspite of the opposition and obstruction of vested interests. As to the Hirakud Dam Project, there is no question, but that it will be in the interest of Sambalpur district and Orissa as a whole.

Further, it will have an all-India importance. With the irrigation, power and navigation facilities made available by the construction of the Hirakud Dam, there will be increased production of food, cheap electricity for the development of key industries and agriculture, and widespread waterways for the transport and distribution of agricultural and industrial produce. Food, key industries and strategic lines of communications are matters of vital concern at present and are likely to assume over-riding importance in the new constitutional set up. The question must, therefore, also be viewed from an all-India angle.

The policy of the Government in respect of compensation should be to give, as far as possible, land in exchange for land and that well ahead of the date of actual submergence. The compensation in kind or cash should be on terms which are equitable and, if anything, generous. Government should assist the people in rehabilitation, and strive to create conditions in the new colonies, which should be a definite improvement on the existing ones. This can be done by setting up model villages and providing them with essential amenities of life, e.g. drinking water, sanitation, public schools, community centres, electricity, etc. Any expenditure on such improvements which is in excess of the compensation allowance in the project, should be met from general revenues as a contribution towards raising the standard of living of the people. Such a scheme of rehabilitation will be welcomed in the long run even by the dispossessed people.

Suitable lands are said to be available in the Government and Zamindari forests, the Barra jungle and Gochar areas. These lands can be reclaimed and made fit for occupation before the people from the reservoir area are moved. In addition, out of the submerged areas, marginal lands to the extent of nearly 20,000 acres will re-appear each year with the depletion of the reservoir, and will be fit for raising one good crop.

The programme of construction of the dam will be so arranged that the actual submergence of lands will take place by stages. No appreciable areas are likely to be affected in the first two years, so that there will be enough time to prepare lands for resettlement. As a further aid, cultivators can be given possession of new lands, six months or so in advance of the date when they are required to vacate their original holdings.

SURVEYS AND INVESTIGATIONS.

A reconnaissance soil survey of the areas to be brought under irrigation and of those set apart for resettlement of people dispossessed from the reservoir area, has been carried out by a special officer. A programme of intensive soil survey is now being undertaken.

Experimental agricultural farms will be set up to study problems of crops and crop yields with special reference to irrigation and fertilisers.

The Mahanadi Valley is rich in valuable forests, consisting of sal, teak, bamboos, paper grasses, etc. The problems of soil conservation, regulation of forest cuttings and re-forestation are receiving careful consideration for purposes of industrial exploitation and silt control and conservation of agricultural lands.

A careful malaria survey of the Mahanadi Valley is being undertaken by a special officer of the Malaria Survey of India.

A fishery specialist is being put on special duty to study the problems of fish culture in the reservoir to be formed by the Hirakud Dam, village ponds and hatcheries.

A detailed economic survey of the area is also being undertaken.

INDUSTRIAL POSSIBILITIES

With cheap hydro-electric power to the extent of 300,000 k.w. made available by the construction of the Hirakud Dam, it will be possible to set up an industrial town in the neighbourhood of Sambalpur, where factories can be installed for the manufacture of cement, iron, steel, aluminium, paper, ferro-alloys, textiles, sugar, cotton, fertilisers, chemicals and other products. Raw materials including coal, iron, limestone, bauxite, timber, grasses, etc. are available within easy reach. If the bulk of the manufactures are concentrated in the neighbourhood of the power stations, considerable savings will be effected in transmission losses, and consequently in manufacture costs. This fact is of particular importance in the manufacture of aluminium and fertilisers.

It is most important that the programme of industrial development should be planned and implemented simultaneously with the programme of power development. In this planning due consideration will have to be given to the requirements of defence, *e.g.*, location and dispersion of industry. The scheme will have to be reviewed in the context of the all-India industrial plan.

INDUSTRIAL RESEARCH

Industrial research should form an integral part of any scheme of industrial development.

FINANCIAL ASPECT

Expenditure.

The project is estimated to cost Rs. 47.81 crores made up as follows:

	Rs.
Dam and appurtenant works	16.16 crores.
Main canal, branches, distributaries and water courses	7.80 crores.
Hydro-electric installations	22.85 crores.
Navigation	1.00 crores.
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	47.81 crores.
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The allocation of costs to different purposes will be:

	Rs.
Flood control	6.11 crores.
Irrigation	11.12 crores.
Power	29.58 crores.
Navigation	1.00 crores.
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	47.81 crores.
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Revenue.

Flood control.--No direct revenue is expected from flood control, but the indirect return will be a saving of nearly Rs. 12 lakhs a year in flood damage to the delta, the reclamation of flooded lands and the increase in food crops as a result of such reclamation through flood protection and irrigation.

Irrigation.—On full development the direct revenue from irrigation will be Rs. 48,40,750. The average water rate for flow irrigation will be Rs. 3.77 per acre and for lift irrigation Rs. 5.27 per acre. As stated earlier, the rate of power for pumping for lift irrigation will involve a certain element of subsidy, but this is fully justified in the interest of food production. The indirect revenue from irrigation will be Rs. 17,50,420, derived by an average increase of Rs. 2½ per acre in the land revenue. An annual revenue of Rs. 80,000 is anticipated from the lease of marginal lands in the reservoir. The gross revenue from irrigation will be Rs. 66,71,170.

The working expenses on irrigation will be Rs. 34,32,167 per year. This will be made up of Rs. 19,16,167 on the maintenance of canals and distribution system, Rs. 12 lakhs cost of electrical energy for pumping and Rs. 3,16,000 for depreciation, maintenance and operation of pumping plant.

The net revenue from irrigation will be Rs. 32,39,000.

Power.—On full development, i.e., 350,000 k.w. installed and a peak load capacity of 300,000 k.w., the gross revenue from power will be Rs. 2,52,00,000. The working expenses, consisting of depreciation, maintenance and operation will be Rs. 79,81,250.

The net revenue from power will be Rs. 1,72,18,750.

The average rate per k.w. year of peak demand will gradually drop, with the progressive rise in load, from Rs. 160 for an installed capacity of 100,000 k.w., to Rs. 150 for 150,000 k.w., to Rs. 120 for 200,000 k.w. and to Rs. 100 for 350,000 k.w. For pumping load the rate per k.w. year of peak demand will be kept uniformly at Rs. 20.

Navigation.—No provision has been made for any revenue return from navigation, for the present.

Return on capital

The total net return from all sources on full development of irrigation and power will be Rs. 204.58 crores. Assuming interest on capital at 3 per cent., the project will begin to pay from the eleventh year. In the 18th year the accumulated interest on direct outlay will just balance the cumulative revenue upto that year. The percentage return, thereafter, will be 4.29 per cent. gross, on the sum-at-charge, thus giving a *net* annual profit of Rs. 61.15 lakhs or 1.29 per cent.

FOOD PRODUCTION.

In addition to the anticipated net annual profit of Rs. 61.15 lakhs, the construction of the Hirakud Dam Project will bring about an annual increase of 340,000 tons in the food production of Sambalpur district and Sonapur State, and a very substantial increase in that of the Delta.

The production of more food is a matter of vital concern to India. It will assume overriding importance with the secession of the rich irrigated areas of Sind and West Punjab. India cannot afford to continue buying food from abroad to feed her growing millions. For one thing, she is not, and will not for long be, in a position to pay for her food imports in manufactured goods. Self sufficiency in matter of food production is the essence of national independence and survival.

OTHER BENEFITS.

Other indirect benefits from the Project will be a considerable increase in employment opportunity for the people in agricultural, industrial, scientific and other pursuits, with consequent increase in their purchasing power and consumption of manufactured goods. This will result in increased income to the State from income tax, excise and other sources. In addition, there will be large increase in the capital assets of the Province in increased land values as a result of irrigation and in the latent mineral wealth brought to the surface for economic utilisation.

PROGRAMME AND POLICY

The dam and the irrigation system are programmed to be completed in five years, and the power installations in fifteen years. It will be possible to start giving both flow and lift irrigation in the fourth year and electricity about the same time.

If it is desired to curtail expenditure in the first instance, the development of power generation and lift irrigation may be slowed down, but the full expenditure on the dam, gravity canals and the first stage of power development must be incurred in any case. This will involve a minimum expenditure of Rs. 35 crores. The balance expenditure of Rs. 12½ crores can be deferred, as necessary, but must be eventually incurred to get the full return from the project.

ORISSA'S OPPORTUNITY

Orissa possesses immense water wealth in her five rivers (particularly the Mahanadi), large areas of cultivable land, big deposits of key minerals and a large population of intelligent and industrious people. By an integrated development of its natural resources and by harnessing of its man power, Orissa can become industrially, economically and politically great. The Mahanadi alone has an irrigation potential of over 20 million acres (if land to that extent is available) and a power potential of over four million k.w., which is nearly as big as that of Sweden, and twice as big as that of Tennessee Valley. The great waterway of the Mahanadi extending from the Central Provinces to the sea with a potential major deep-sea port at Chandbali or Dhamra will provide a most valuable artery of traffic.

Orissa's present position is analogous to that of the backward, agrarian Ukraine in the U.S.S.R. as it was before the completion of the Dneiper Dam in March 1932. The construction of the Dneiper dam transformed Ukraine into a prosperous agricultural and industrial area producing coal mining, metallurgical, power and electrical equipment; steam locomotives, railway cars and automobiles; and aluminium, iron, steel, high grade alloys, soda, nitrates, super-phosphates and other chemicals. The construction of the Hirakud dam will similarly transform Sambalpur and Orissa into a prosperous agricultural and industrial area with unlimited possibilities for service to the nation in peace and war.

The construction of the Hirakud dam is, therefore, of importance not only to the district of Sambalpur, Orissa Province and the Eastern States, but also to India as a whole. It will give a most welcome lead to other parts of India where, as in the case of Orissa, the water wealth of the region, which is now being wasted to the sea, can be harnessed in the service of the nation. It will mark the beginning of an era of higher standards of living for the common man, of freedom from floods, famines, want, drudgery, and disease.

RECOMMENDATIONS

- (1) The Hirakud Dam Project should be sanctioned forthwith. The feasibility, utility and economics of the project should be judged in the light of the greater interest of the people of Sambalpur and Orissa as a whole. The greater good of the community must have priority over the interest of individuals or groups. Vested interests must not be allowed to stand in the way of the country's progress, nor must the resources of the region be allowed to cause destruction, be wasted or lie dormant on that account.
- (2) Immediate steps should be taken to decide the programme and policy of resettlement of the people whose lands will be submerged in the proposed reservoir.
- (3) Immediate steps should be taken to set up a cement factory near the dam site and to place orders for the necessary plant and equipment. It will take about 18 months from the date of placing of the order to the time this factory starts producing cement for the construction of the dam.
- (4) Immediate action should be taken to set up an iron and steel factory in Sambalpur. With cheap power available at the site and iron ore, coal, limestone and fuel wood obtainable within easy reach, an iron and steel factory at this place should prove to be a great economic success.
- (5) In addition to setting up the above two industries, immediate steps should be taken to plan and implement the programme in respect of other industries which can be set up in the neighbourhood of the Hirakud dam, e.g., aluminium, ferro alloys, fertilizers, paper, textiles, chemicals, etc.
- (6) The industrial plan for Orissa should be reviewed in the context of the all-India industrial plan with special reference to requirements of defence. This assumes special importance in view of the latest constitutional developments.
- (7) Special consideration should be given to the food production aspect of the project as, with the secession of the richest food producing areas, the rest of India will have to make serious efforts to solve her food problem and become self-sufficient.
- (8) Special consideration should also be given to agricultural, industrial, navigational and pure research by setting up agricultural farms, pilot factories and research laboratories with a view to keeping abreast of latest developments and effecting new improvements. The planning of this research should take special note of defence requirements.
- (9) Early enquiry should be instituted into the working of the irrigation system in the delta with a view to ascertaining the reason for its being unproductive and the possibilities of improvement and further extensions.

SIMLA.

June 12, 1947.

A. N. KHOSLA, I.S.E.,

Chairman,

Central Waterways, Irrigation
& Navigation Commission.

SALIENT FEATURES OF THE HIRAKUD DAM PROJECT.

I. THE DAM AND RESERVOIR.

Location.

On the river Mahanadi below the confluence of the Ib river and about 9 miles up stream of Sambalpur town

Catchment area.

Above Sambalpur 32,200 sq. miles.

Rainfall

Mean annual (1900-45)	..	..	..	..	..	54.38 inches
Maximum (1919)	..	..	..	..	..	71.21 "
Minimum (1902)	..	..	..	..	..	37.02 "

Stream flow.

Maximum flood estimated	..	..	..	..	..	9,42,000 cusecs. (1,110,000) cusecs.
Mean annual discharge (1926-46)	..	..	..	..	..	68,000 cusecs.
Minimum discharge	..	..	..	..	..	900 cusecs
Mean annual run-off (1926-46)	..	..	..	..	..	50 00 m.a.ft *
Maximum run-off (1919)	..	..	..	..	..	69.90 m a.ft.
Minimum run-off (1902)	..	..	..	..	..	20.61 m.a.ft.

Reservoir.

Provinces and states affected Orissa Province.

Operating levels at dam :

Top of gates (Provisional)	..	..	..	..	..	R. L. 630.5.
Full Reservoir level	..	..	..	..	..	R. L. 625.00.
Spillway crest (Provisional)	..	..	..	..	..	R. L. 605.00.
Dead storage level	..	..	..	..	..	R. L. 580.00.
Length of water spread at R. L. 625.00	..	..	..	..	..	34 miles.
Length of shoreline at R. L. 625.00	..	..	..	..	..	156 miles.
Reservoir area including river bed at R. L. 625.00	..	..	..	..	..	135,000 acres.
River bed area	..	..	..	..	..	25,000 acres.
Cultivated area submerged	..	..	..	..	..	70,000 acres.
Storage capacity at R. L. 625.00.	..	..	..	..	..	5.30 m a.ft
Storage capacity at R. L. 605.00	..	..	..	..	..	3.07 m.a.ft.
Storage capacity at R. L. 600.00	..	..	..	..	..	2.58 m.a.aft.
Dead storage capacity at R. L. 580.00	..	..	..	..	..	1.20 m.a ft.
Live storage capacity at R. L. 580.00 to R. L. 625.00.	..	..	..	..	..	4.10 m a ft.

Dam Materials and type

Concrete gravity overflow type	..	..	..	..	..	5,000 ft
Earth and rock rolled-fill dam	..	..	..	..	..	10,700 ft.
Total length including control works	..	..	..	..	..	15,700 ft.
Earthen dyke—right	..	..	..	..	..	34,500 ft.
Earthen dyke—left	..	..	..	..	..	27,000 ft.
Maximum height above deepest river bed	..	..	..	..	..	150 ft.
Top of dam—Road level	..	..	..	..	..	R. L. 642.00

Appurtenant works.

Navigation locks butting the right side abutment; swinggear, power house; spillway; fish ladder; timber shoot.	..	..	..	..	..	R. L. 605.00
Crest of spillway (Provisional)	..	..	..	..	..	R. L. 605.00

Gates

Drum gates, Stoney gates, Deep set sluices or Ganesh Iyer Volute siphon or a combination of two or more of these.	..	..	..	..	..	R. L. 570.00
Sill of Head Regulators. (Provisional)	..	..	..	..	..	R. L. 570.00

Subsidiary dam.

Material and type; Earth and rock rolled-fill dam and of the same design as dykes.

II. IRRIGATION.

Sambalpur district and Sonepur State	Gross commanded area	..	..	1,313.0 acres.
Net irrigable area	..	..	..	875,210 acres.
Irrigation per year (both crops)	..	..	..	1,094,953 acres.

* m.a.ft. = million acre ft. = 43,560 million cubic feet.

Main Canals and Branches.

Name of channel.	Length in miles	Gross commanded area acres.	Net Irrig- able area. acres	Full supply discharge in cusecs.
Left side lift canal	app 33	110,000	73,300	737
Left side flow canal	50	192,000	128,000	1,287
Irrigation canal from power channel	37	250,000	166,710	1,676
Right side flow canal	40	300,000	200,000	2,013
Right side lift canal	70	436,000	290,500	2,920
Foreshore canal	8	25,000	16,700	167
	238	1,313,000	875,210	8,800

Additional yield in food grains 340,000 tons annually.

Value of additional food grains per year. .. Rs. 3.5 crores.

Delta Irrigation.

There is possibility of considerable improvement and extension of irrigation in the delta. But this has not yet been examined and no credit taken on this account in the project.

III POWER.**Upper Power House.**

Reservoir Water levels Maximum	R. L. 625.00
Minimum	R. L. 580.00
Tailwater levels Maximum	R. L. 515.00
Minimum	R. L. 512.00
Range of head Dry months	65 to 113 ft.
Monsoon months	85 to 113 ft

Lower Power house.

Balancing reservoir water levels Maximum	R. L. 512.00
Minimum	R. L. 508.00
Tailrace level Maximum	R. L. 432.00
Minimum	R. L. 416.00
Range of Head Dry months	92 to 96 ft.
Monsoon months	80 to 90 ft

Installed Capacity.

Proposed in Project	350,000 k.w
Ultimate	475,000 k.w.

Hydraulic turbines.

	Proposed in project.	Ultimate.
Upper Power House	6 units of 25,000 k.w.	8 units.
Lower Power House	8 units of 25,000 k.w.	11 units.

Power Channel.

Length from dam to where it enters the balancing reservoir	12 miles.
Capacity	18,000 cusecs

Tail race channel.

Length	10 miles.
Capacity	14,160 cusecs to 21,000 cusecs.

Transmission lines

Hirakud to Sambalpur—Double line 132 K.V. 6 circuits	7 miles.
Upper Dam to Lower Power House—Double 132 K.V. line 4 circuits	20 miles.
Sambalpur to Jamshedpur—Double circuit 132 K.V.	160 miles.
Sambalpur to Cuttack—Double circuit. 132 K.V.	200 miles
Hirakud towards Duduma (provisional) 132 K.V.	150 miles.

To Pumping Stations—33 K.V. line (132 K V. possible upto main pumping station.)

IV. NAVIGATION.

Lock : one set at the upper dam and one set at the subsidiary dam for a total lift of 110 ft. each set. The lock chambers will be 60' × 360' (provisional).

Regulated discharge available in the river below Hirakud in dry months .. 8,800 to 14,000 cfs.

By removing obstacles and providing conservancy measures 500-800 tons tow can ply from sea to Dab and then to Hirakud pool.

V. FINANCIAL.

Expenditure :

Total cost of the project :

Flood control	..	..	..	..	Rs 6 11 crores.
Irrigation	..	..	..	..	„ 11 12 „
Power	..	..	..	..	„ 29.58 „
Navigation	..	..	..	..	„ 1 00 „

Rs. 47 81 crores.

Average Rates :

Irrigation :

Increase in land revenue	..	..	Rs. 2 per acre of net irrigable area.
Water rate for flow irrigation	..	..	Rs. 3.77 per acre irrigated.
Water rate for lift irrigation	Rs. 5.27 per acre irrigated

Power.

Pumping load	Rs. 20 per k. w. year of peak demand
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Other loads :

Installed capacity	100,000 k.w.	Rs. 160 per Do.
Installed capacity	150,000 k.w.	Rs. 150 Do.
Installed capacity	..	..	200,000 k.w.	Rs. 120 Do.
Installed capacity	..	..	250,000 k.w.	Rs. 120 Do.
Installed capacity	..	..	350,000 k.w.	Rs. 100 Do.

Annual Gross Revenue (on full development).

Flood control (Direct)	..	..	Nil.
Irrigation	..	..	66.71 lakhs.
Power	..	..	252.00 lakhs.
Navigation	..	..	Nil for the present.
Total	..	..	318.71 lakhs.

Net Revenue.

From seventeenth year from start of construction	..	Rs 204.58 lakhs
Return on capital of 47.81 crores	..	4.29%.
Interest on capital at 3%	..	Rs 143.43 lakhs.
Annual profit (204.58—143.43)	..	Rs. 61.15 lakhs.

CHAPTER I.
INTRODUCTION.
HISTORY OF ORISSA.

Orissa formed the northern part of the ancient Kingdom of Kalinga and parts of Mahakosala, which were settled by the Aryan conquerors long before the times of Asoka who annexed the territory in about 260 B.C. The Kingdom of Kalinga at one time extended from the Ganges on the north to Cape Comorin on the South. The people were adventurous and carried their flag as far as Java and Sumatra in South East Asia. A few ancient monuments at Puri bear witness to that ancient glory. Orissa remained independent under her own Kings up to 1575 A.D., when it was conquered by the Pathans from Bengal. The Pathans were, however, turned out shortly afterwards by Raja Man Singh, the General of Emperor Akbar and the country was included in the Moghul Empire and attached to Bengal. It was conquered by the Mahrattas in 1750 from whose rule it passed on to the British in 1803. During the British rule, Orissa was originally attached to Bengal. In 1912 it became part of the Province of Bihar and Orissa. In 1936, with the introduction of the Government of India Act of 1935, Orissa was constituted into a separate province. No great constructional work was undertaken during nearly four centuries of Moghul, Mahratta or British rule.

POPULATION.

The total area of Orissa and the Eastern States is 50,349 square miles, out of which that of Orissa is 32,198 square miles. The total population of the region is 11,752,275, of which 8,728,544 is in Orissa and the rest in the Eastern States. The density of population in Orissa is thus 271 per square mile against 166 in the Eastern States. The average density over the region is 233 per square mile. In Orissa the three coastal districts, Cuttack, Balasore and Puri, have a density per square mile of 536, 501 and 442 respectively against an average density of 271 for the whole of Orissa, which is evidently due to the fact that the soil in these districts is comparatively rich due to frequent flooding, and that the crops are partially protected from draughts by irrigation. A statement showing the area, population (according to 1941 census) and density of population by districts and States is given below :—

District or State.					Area in sq. miles.	Population.	Density per sq. mile.
Orissa—							
Cuttack					4,571	2,431,427	536
Balasore					2,194	1,029,430	501
Puri					2,451	1,101,939	442
Sambalpur					5,419	1,182,622	249
Ganjam (Plains)					3,315	1,392,188	420
Ganjam (Agency)					4,373	463,076	106
Koraput					9,875	1,127,862	115
Total ..					32,198	8,728,544	271

District or State.					Area in sq. miles.	Population.	Density per sq. mile.
Eastern States—							
Athgarh	..	..	..	..	163	55,498	340
Talcher	..	..	..	..	388	86,432	223
Nilgiri	..	..	..	..	263	73,109	274
Keonjhar	..	..	..	.	3,206	529,786	165
Pallahara	..	..	..	..	450	34,130	76
Athmallik	..	..	..	..	723	72,765	101
Dhenkanal	..	..	..	..	1,428	324,212	227
Hindol	..	..	..	..	291	58,505	201
Narsinghpur	..	..	..	..	204	48,448	237
Baranba	..	..	..	..	143	52,924	370
Tigra	..	..	..	..	46	26,331	573
Ehandpara	..	..	..	..	229	87,341	386
Nayagarh	..	..	..	..	562	161,409	287
Ranpur	..	..	..	..	204	51,366	252
Daspalla	..	..	..	..	556	53,833	97
Baudh	..	..	..	..	1,156	146,175	127
Bamra	..	..	..	..	1,974	178,277	90
Rairakhol	..	..	..	..	857	38,185	45
Sonepur	..	..	..	..	948	248,873	262
Bonai	..	..	..	..	1,280	92,537	72
Gangpur	..	..	..	..	2,477	398,171	161
Seraikela	..	..	..	..	446	154,844	332
Kharsawan	..	..	..	..	157	50,580	322
Total					18,151	3,023,731	166
GRAND TOTAL					50,349	11,752,275	233

LANDS.

Nature has divided this tract in three distinct groups, the upland plateau, the central hilly portion traversed by the eastern ghats, and the delta area. The upland plateau consists of a wide expanse of fairly open country fringed by forest clad hills on the west, north and east and intersected by the river Mahanadi. Speaking broadly it is an undulating upland tract the general slope of which is from north to south but it is much broken by ragged ranges of hills, and is traversed in all directions by drainage channels leading from the hill ranges to the Mahanadi. Isolated hills rising abruptly from the plains are also common, and a considerable area consists of ground cut by ravines or ridges. The elevation of the plain portion falls from nearly 750

feet on the north to 480 feet at Sambalpur. One of the most fertile parts of this plateau is the Bargarh plain which consists of an undulating tract of country sloping from the foot of Bara-pahar hills on the north to the borders of Sonepur and Patna States on the south. Much of the forest land has been brought under cultivation but some of the surface is too high or too broken for tillage and large areas now lie idle.

The usual classification of soils in these uplands is based on their position or level, which in an undulating country is an important consideration to the cultivator. The four main divisions are At, Mal, Berna and Bahl. 'At' areas consist of high lying lands on a water-shed, which are dependent for moisture on rainfall. They are as a rule sandy and are cultivated with oil seeds, cotton and pulses. The term 'Mal' is used for slopes which are terraced to catch the drainage water coming down from the uplands. Lower terraces are watered and cultivated. There is a great difference in fertility and in security of cropping between them. The higher 'Mal' lands are light and dry yielding early crops which receive little more attention than the chance crops on 'At' lands. The lower 'Mal' lands get excellent drainage and grow good varieties of rice. The term 'Berna' denotes lands towards the bottom of depression, which receive the drainage from the slopes on either side and also from the drainage line between them. Berna lands vary considerably according to their steepness and the stage of their development. 'Bahl' is a term used for flat lands at the bottom of a depression or drainage line. The chief distinction between 'Berna' and 'Bahl' being that the former is narrow and steep while the latter is wide and level. The best 'Bahl' lands are served by irrigation tanks. Bahl, Berna and Mal lands are, as a rule, under rice, for the wash of rain tends to bring fertile silt down to them, while 'At' lands are used for other crops.

The portion separating the plateau uplands from the delta consists of a chain of hills with thickly wooded slopes and fertile valleys between. The greatest distance of this hilly region from the sea coast is about 60 to 70 miles, but in many places it does not exceed 15 to 20 miles. The hills do not consist of long continuous ranges but are generally irregularly scattered in groups running east and west. With the exception of a few naked bluffs they are for the most part covered with vegetation. The forest cover in this area as well as the hills in the plateau is of three main types. The most valuable type consists of sal. The second type consists of mainly deciduous species with few or no sal or bamboos, and the third type consists of bamboos nearly pure but often intermixed with species of the second type or with a few sal.

The delta area is nearly 8,000 square miles out of which the central portion of 3,000 square miles is particularly subject to floods. It is, however, the most fertile and densely populated tract in Orissa.

AGRICULTURE.

Orissa is mainly an agricultural province. The main crops are rice, cereal and pulses, sugarcane, oil seeds, betel and some gram. Some jute is also grown in Cuttack district and to a lesser extent in Balasore. Water is available only during the rainy season—June to September; therefore, 70 per cent. of the cultivated area is under rice. There is no second crop worth the name since water is not available during the remaining months,—October to May. The

cultivation of money crops like sugarcane and tobacco has not received much attention for this very reason.

HEALTH.

Orissa is not a particularly healthy province, but coastal towns are worse off than Sambalpur and other places which are further inland. One of the principal diseases of the province is fever. All cases of kala-azar, typhoid and influenza are generally lumped together by the village chaukidars under the term fever. Malaria is most prevalent but it is not considered to be the direct cause of many deaths. Intestinal diseases such as dysentery and diarrhoea are also common. The principal source of infection in these cases is undoubtedly impure water supply. People, as a rule, drink tank water. Outbreaks, therefore, occur in hot weather when supplies are shrinking and water becomes polluted, stagnant and impure, and is at the same time required for irrigation. Amongst other diseases, not usually fatal, the most prevalent are elephantiasis and hook worm. The former is very common and probably 25 persons in every thousand suffer from it. The hook-worm disease which is very prevalent and makes the people prone to lethargy is essentially a "low income" disease and can only be eradicated by improvement in the hygienic and economic conditions of the people. Annual birth rate in the province is in the vicinity of 35 per square mile while death rate is of the order of 28 per square mile. Comparing with other provinces, while the birth rate is lower than most of the other provinces, the death rate is much higher excepting perhaps Central Provinces. This is evidently due to low vitality of the people on account of poverty and unhealthy climate resulting from poor drainage and stagnating pools, which afford breeding grounds for malaria mosquitoes.

COMMUNICATIONS.

The province is not well served with up-to-date means of communications. The Bengal Nagpur Railway, between Calcutta and Madras, passes through Cuttack and serves only the coastal area of the province. Another main line of this railway skirts the northern portion of the province and the Raipur-Vizianagram branch the western portion. Besides these there are two small Branches, one from Cuttack to Talcher and the other from Jharsuguda to Sambalpur.

The rivers are almost dry for most part of the year. For internal communication, therefore, the province depends mainly on roads which also do not provide through communications, as there are no bridges on any of the rivers. While the trunk roads are metalled most of the other roads are unmetalled and are passable only during fair weather.

In the postwar development schemes, however, a few railway lines are proposed through Orissa and Eastern States. One would be an extension of Jharsuguda-Sambalpur line to Katabunji on the Raipur-Vizianagram line and another from Sambalpur to Sonapur and thence to Khurda Road on the Calcutta-Madras line. These will necessitate a railway bridge across the Mahanadi river upstream of Sambalpur town. The proposed Hirakud Dam will provide the first road bridge across the Mahanadi.

RIVERS OF ORISSA.

The river basins which together go to make up the Orissa Province and the adjoining Indian States are the Mahanadi, the Brahmini, the Baitarani, the Burabalong, and the Subarnrekha. The latter two are relatively smaller and have special problems of their own ; and do not come within the scope of this project. The three principal rivers, the Mahanadi, the Brahmini and the Baitarani have several common features. They all run parallel. All have their origin in the hilly countries of the Central Provinces or Orissa and all run directly into the sea. Between them, they carry each year 107 million acre ft. of water to the sea, a volume which will fill more than three times the biggest man made lake in the world—Lake Mead (with a capacity of 32 million acre feet) formed by the Boulder Dam in U.S.A.

The Mahanadi.

The Mahanadi is the largest of the three rivers with a total length of 533 miles. It rises near Sihawa in the extreme south-west of Raipur district in Central Provinces. In the first part of its course it flows to the north and drains the eastern portion of Raipur. On entering the Bilaspur district it receives the waters of its first great effluent, the Seonath. It flows in an easterly direction through Bilaspur, its principal tributaries being the Tonk and the Hasda. It then enters Sambalpur and turning south above Padampur flows south and south-east through the District. Its tributaries here are the Ib, Ong and Tel and numerous minor streams. In Sambalpur it becomes a river of the first magnitude with a width of more than a mile. It subsequently forms a series of rapids until it reaches Dholpur. During the rainy season the water covers the rocky beds and suffices to drift the huge drafts of timber. At Dholpur the rapids end and the river rolls its unrestrained waters straight towards the outermost line of the eastern ghats. This mountain line is pierced by a gorge of 40 miles in length. The Mahanadi finally leaves the tributary states and pours down on the Orissa delta, from between the two hills a mile apart at Naraj about 7 miles west of Cuttack. It traverses Cuttack district from west to east throwing off numerous branches and falls into the Bay of Bengal through several channels near the False Point.

The catchment area of the Mahanadi above Naraj is 51,000 square miles. It has an average annual rainfall of 53.17 inches. Its maximum flood discharge at Naraj is calculated as 1.6 million cubic feet per second. In the dry season, however, the discharge dwindles to about 2,500 cubic feet per second, the lowest at record being 1500 cusecs. The mean annual runoff of the river at Naraj is 74 million acre ft. The mean annual runoff of the Indus at its debouch in the plains at Kalabagh is 87 million acre ft ; of the Columbia river at the Grand Coulee Dam 80 million and of the Nile at the Aswan Dam 66 million acre feet. This runoff of the Mahanadi at Naraj will fill the reservoir formed by the Mettur Dam in Madras more than 30 times.

The Brahmani.

The Brahmani has a much smaller catchment area *viz* 14,000 square miles. The mean annual rainfall in the catchment is 57.91 inches and the mean annual runoff about 22 million acre ft.

The Baitarni

The Baitarni has a catchment area of only 4,000 square miles. The mean annual rainfall in the catchment area is 53.58 inches and the runoff 5.9 million acre ft.

General Hydrological Features.

The main hydrological features of the three river basins are given in Table I.

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TABLE I.
(From Prof. Mahalanobis's Report).

Catchment.		Normal Rainfall in inches 1891-1926.						Monsoon per centage to total Rainfall	Normal Rainfall (Average 1891-1945) inches.	Mean Annual runoff as derived from the 1926-45 values in million acre ft.	Mean Annual discharge in cu. sec.
Sections.	Area in Sq. miles.	Name of the end of Section.	No. of Rainfall Stations.	Winter December to Feby.	Summer March to May.	Monsoon June to September	Autumn October to Novr.					Annual Jany. to Dec.
<i>Mahanadi.</i>											
Mahanadi V ..	11,300	Changori	13	1.91	2.19	40.83	2.66	47.59	85.80	..	..
Mahanadi IV ..	6,600	Seorinarayan	3	1.65	2.62	45.78	3.09	53.14	86.15	..	..
Mahanadi III ..	14,300	Sambalpur	7	1.81	2.15	52.96	2.58	59.50	89.01	..	..
Total up to Sambalpur ..	32,200	..	23	1.79	2.32	46.52	2.78	53.41	86.99	54.64	68,000
Mahanadi II ..	12,400	Sonepur	6	1.49	3.06	47.49	2.78	54.82	86.63	..	100,000 at Tikkerpara
Mahanadi I ..	6,400	Naraj	10	1.72	5.23	42.73	5.31	54.99	77.71	..	..
Total for Mahanadi ..	51,000	..	39	1.76	3.13	44.90	3.38	53.17	84.45	..	101,000
Brahmani II ..	8,400	Bonaigarh	9	2.52	3.52	49.10	3.38	58.52	85.90	..	..
Brahmani I ..	5,600	Jenapore	7	1.80	4.93	45.80	4.56	57.00	80.22	..	..
Total for Brahmani ..	14,000	..	16	2.21	4.14	47.66	3.90	57.91	82.31	..	30,000
Baitarni ..	4,000	Akhyapada	6	2.08	7.06	38.84	5.60	53.58	72.49	..	8,000
Delta ..	3,100	..	12	1.80	6.35	43.15	8.37	59.67	73.31	..	7,000
Total ..	..	..	..	..	..	..	..	..	..	107.03	146,000

For boundaries of catchment and subcatchments see plate V.

THE PROBLEM OF ORISSA.

The enormous volumes of water carried by the three major rivers which constitute the potential wealth of Orissa are at present running to waste and causing destruction and disease in their passage to the sea. The distribution of rainfall and, consequently, the river supplies, through the year suffer from maladjustment. There is too much water during the rains and too little of it during the rest of the year, with the result that "Orissa is haunted by the two spectres of flood and drought, and of these the latter is the most terrible". Orissa continues to be a province of one crop and a precarious one at that.

DROUGHTS AND FLOODS.

Previous to the inception of the Orissa Canal System, however limited its scope, droughts and famines were of frequent occurrence. Historical records show that terrible famines occurred in the 14th, 15th and 16th centuries. In the memorable famine of 1770, people were reported to have been dying by hundreds and thousands. Nearly a century later came the great Orissa famine of 1865-66. The rainfall in 1865 was scanty and ceased prematurely. The food crops failed and it was estimated that nearly one million people died in the district of Cuttack alone. In the district of Puri, nearly 40 per cent. of the population perished. Then followed the flood of 1866. Crops and property were destroyed and what the drought had spared, was engulfed in the wide flood waters. Hundreds of square miles were submerged from 5 to 45 days with water standing up to a depth of 10 ft.

SIR ARTHUR COTTON'S WORK.

Of recent years the flood problem in the Orissa delta has engaged considerable attention. The first serious attempt to tackle the problem was made in 1858 when Sir Arthur Cotton, one of the foremost pioneers of modern irrigation in India, was asked to report on the harnessing of the waters of the Orissa rivers. As a result of inspection and discussions with local officers he made certain recommendations which comprised the construction of weirs across the Mahanadi, Brahmani and Baitarni rivers, irrigation canals throughout the delta suitable for navigation, drainage channels between all irrigation channels, and embankments. These recommendations were, however, not given effect to as the scheme was not "productive" according to the recognised standards of the time and as the dry weather flow was too small for any large scale irrigation development.

FLOOD ENQUIRY COMMITTEE OF 1927.

In November 1927, the Government of Bihar and Orissa, appointed a Committee of three experienced Engineers to investigate the flood problem in Orissa. The Committee travelled extensively in the Delta and adjoining areas, recorded evidence and heard the representations made by the people. Some of the recommendations of the Committee were :—

- (1) The construction of flood control reservoirs on any of the rivers was not practicable.
- (2) Some of the estuaries should be opened up and cuts made in places through the sand dunes along the sea coast to allow the free passage of

floods into the sea. The embankments in the semi-protected areas should also be removed as they obstructed flow and were liable to breaches.

(3) Private reclamations along the coast should not be permitted.

(4) The Orissa Coast Canal and other Coastal Canals were to be abandoned as they were serving little purpose for irrigation or transport, but were obstacles to the free flow of floods.

(5) Irrigation by pumping to be encouraged.

Briefly put, the Committee recommended against control reservoirs as being impracticable, and against any form of embankments because they obstructed flow.

Though a large number of Committee's proposals were investigated by the local officers, no progress was made in giving effect to any of them for want of funds, and the opposition of vested interests to measures like the removal of embankments, which though possibly of general benefit to the locality as a whole, prejudicially affected individual interest.

SIR M. VISVESVARAYA'S REPORT OF 1937.

In the monsoon season of 1937, there were high floods in the deltaic tracts of the province causing considerable damage and the Government sought the advice of Sir M. Visvesvaraya who after a study of old records and other official documents, sent them a note making certain recommendations for framing a comprehensive plan for dealing with the flood problems. For this purpose he advised that particulars should be collected for each river in the delta under the following heads :—

- (1) Hydraulic data.
- (2) Areas requiring protection.
- (3) Estimates of costs of proposed works including reservoirs.
- (4) Further investigations of flood control reservoirs.

He particularly laid emphasis on the investigation of the feasibility of constructing flood control reservoirs on any of the three main rivers, but particularly on the Mahanadi and stated that "reservoirs if constructed will be of value to hold up the floods temporarily and release them gradually so as to run to waste at a harmless rate. The (1928) Committee considered that the proposals under this head are not practicable. The reason seems to be that such reservoirs will have to be outside the province and therefore beyond the jurisdiction of Orissa Government. Another reason expressly stated is that on a river of the size of the Mahanadi, a reservoir could be constructed only at a gigantic cost.

"Unless the Committee have based their conclusions on dependable data—which however are not revealed in their report—it seems necessary to investigate this question more fully.

"It may be mentioned that even on such enormous rivers like the Mississippi and its tributary, the Ohio River (in the United States of America), the possibility of constructing flood storage reservoirs is receiving consideration.

"This remedy seems to be beyond the resources of the province of Orissa at the present time. For such a remedy to succeed in the near future, it will have to be taken up by the adjoining province or provinces at the same time and treated as an inter-provincial problem. But if this remedy is definitely ruled out, the investigations conducted and the reasons for abandoning the proposals should be clearly placed on record."

“The writer is well aware”, he stated, “that on account of their cost and the difficulties attendant on inter-provincial cooperation, there is small prospect of the idea materialising in the near future. But it is desirable to make some preliminary investigations to see how the question stands at present, and whether there is any prospects of its being taken up later when the Province is able to finance such undertakings. If a reservoir is constructed, it may prove useful in several other ways as well—for extending irrigation, generating electric power, etc. Once floods come under effective control, the whole area may be transformed into a prosperous region.”

This approach of Sir M. Visvesvaraya to the flood problem of Orissa was most realistic and constructive. In pointing to the possibilities of conservation of the river waters for multipurpose development, he was ahead of his time. His recommendations if implemented would solve not only the problem of floods but that of droughts and the general backwardness of the people.

FLOOD ENQUIRY COMMITTEE OF 1938.

Sir Visvesvaraya also suggested a committee of expert Engineers to go into this question. The Orissa Government accordingly appointed a committee in 1938 consisting of Mr. M. G. Rangaiya, Mr. C.C. (now Sir Claude) Inglis and the Chief Engineer of Orissa to investigate the flood problem of Orissa. In 1938-39 this Committee submitted its first interim report, which contained separate recommendations relating to the whole delta, and the individual deltas.

Regarding the whole delta, the Committee felt that the policy to be followed for flood protection should be the improvement of main rivers by—

- (a) the control of the discharges and the silt charges at the bifurcations of the rivers,
- (b) providing better outlets to the sea,
- (c) adequately strengthening the embankments and preventing breaches both in embankments and in the natural banks, and
- (d) the provision of high level escapes.

The Committee also recommended that the question of detention or storage reservoirs be only taken up for investigation after other cheaper methods have been tried and their results were known, and that judging from the loss caused to the country by flood damage, Government would be justified in spending a much larger amount than has been incurred in the past on flood protection.

VISIT OF SIR VISVESVARAYA IN 1939.

In 1939, Sir Visvesvaraya visited the Province at the instance of the Minister for Public Works the Honourable Mr. N. Kanungo and made a hurried tour of the area. He was glad that flood protection by constructing storage reservoirs in the upper reaches of the rivers had received some consideration, but he appreciated the difficulties regarding construction of these because of State boundaries and poor financial condition of Orissa Province.

FLOOD ENQUIRY COMMITTEE REPORT OF 1940.

In 1940, after a study of the data collected the Committee was of the opinion, that :

- (a) To improve the river it is necessary
 - (i) to improve the outfall conditions :

(ii) to control the distribution of water and sand entry at the heads of channels, and

(iii) to restrict the number of channels.

(b) Without double embankments, deltaic rivers break up and deteriorate. Double embanking in conjunction with other measures recommended, retards or prevents such deterioration,

(c) Double embankments necessitate the provision of high level escapes. With the improvement of the river channels the depth of spill through these escapes should be gradually reduced.

(d) Control by double embankments and escapes should be combined with suitable drainage of the basins between rivers.

The recommendations made in 1940 Flood Enquiry Committee Report in respect of embankments were the opposite of those made by the Committee of Three in 1938.

THE CUTTACK CONFERENCE 1945

Finally in 1945, the problem was referred to the Government of India who passed it on to the Chairman, Central Waterways, Irrigation and Navigation Commission, for investigation. The Chairman (Mr. A. N. Khosla) visited Orissa in May of that year. As a result of local inspection, study of previous reports and discussions with Mr. B. K. Gokhale, C.S.I., C.I.E., I.C.S., Adviser to His Excellency the Governor of Orissa and Rai Bahadur Brij Narayan, I.S.E., Chief Engineer, Public Works Department, he came to the conclusion that the only cure for the many troubles of Orissa, namely floods, drought, poverty and disease, lay in the control, conservation and utilisation of the enormous water wealth of its rivers by means of storage dams. In this way it would be possible to control floods and provide irrigation, navigation, power generation, fish culture and recreation facilities, coupled with anti-malarial measures. This was, in effect, the conclusion of Sir M. Visvesvaraya in 1937, revived in concrete form in the light of successful experiments in multipurpose river valley developments carried out elsewhere e.g., the Boulder Dam Project, the T.V.A., the Columbia Basin Development, the Central Valley Development in U.S.A.

Mr. Khosla's proposal for the immediate investigation of the Mahanadi for multiple-purpose development to be followed later on by similar investigations of the Brahmini & Baitarani, received the general approval of the Governments of Orissa, Central Provinces and the neighbouring States at a meeting of their representatives held at Cuttack on the 8th November 1945, under the chairmanship of the Honourable Dr. B. R. Ambedkar, Member for Labour in the Government of India (Appendix I(i)). At this meeting it was also agreed that the Central Waterways, Irrigation and Navigation Commission would undertake all necessary surveys and investigations.

THE HIRAKUD DAM

The foundation stone of the Hirakud Dam was laid by His Excellency Sir Hawthorne Lewis, M.A. (CANTAB), K.C.S.I., K.C.I.E., J.P., I.C.S., Governor of Orissa on 15th March 1946 (Appendix I(ii)).

CHAPTER II.

MAHANADI VALLEY DEVELOPMENT**THE UNIFIED BASIN-WIDE PLAN**

The Mahanadi—literally, the Great River—has a catchment area of 51,000 square miles at its debouch in the plains, an area as big as that of England and 10,000 square miles more than the catchment area of the Tennessee river. It has a mean annual runoff of 74 million acre feet, which is almost five times that of the Colorado River in the U.S.A. at the site of the highest dam in the world, the Boulder Dam. The mean annual runoffs of the Indus in the Punjab, Columbia in the U.S.A. and the Nile in Egypt are 87,80 and 66 million acre feet respectively.

The mean annual discharge of the Mahanadi would work out to about 100,000 cusecs, which is nearly 2/3rd of the total discharge of all the canals and irrigation wells in India, which, between them, irrigate some 70 million acres of land each year.

The fall in the river bed from where it leaves the Central Provinces to Cuttack is nearly 580 feet. If most of the water of the river could be conserved and utilised in conjunction with the available head, it should be possible to afford complete flood control, irrigate every available acre of land, generate four to five million kilowatts of power for industrial, agricultural and domestic purposes, make the river navigable in a length of over 350 miles for heavy draft vessels providing cheap transport for the industrial and agricultural produce of the valley and to carry out fish culture on a large scale to provide protective foods to the masses.

The optimum development of river valleys for multiple purposes is the objective of all schemes of modern planning and development. A large number of river valleys are now being investigated on these lines all over the world—notably in U.S.A., India and China. The development of the Tennessee Valley by the T.V.A. is a recent example of how a river's flow can be utilised to benefit multiple purposes. "On the Tennessee River 26 multiple-purposes reservoirs are operated as a unit (gross storage capacity 21,000,000 acre ft. of which 13,000,000 is useable), so regulating the flow as to produce a minimum discharge of about 30,000 cubic ft. per second where under natural conditions, the discharge had ranged from 5,000 to 475,000 cubic ft. per second (This range in the case of the Mahanadi is from 1,500 to 1,600,000 cubic ft. per second). Benefits that accrue are many. Over two million kilowatts of generating capacity are made available. The navigable channel has been extended up the river 650 miles to Knoxville (9 ft. draught). Coordinated operation of flood gates has removed the threat of serious floods. Other benefits tangible and intangible are numberless." The Tennessee Valley has a population of 2½ million people of whom only about a quarter live in cities; about half are actually farm dwellers. The Colorado, the Central Valley and the Columbia rivers in U. S. A. have been similarly developed for multiple-purposes though with fewer dams. A comprehensive plan, more ambitious than that of the T.V.A., has been worked out for the development of the Missouri Valley, and is being implemented.

The basin-wide plan for the development of the Mahanadi Valley should normally comprise the construction of a series of dams on the main river and its major tributaries and of the allied irrigation, power and navigation works. This overall plan will, for its implementation, involve a great deal of time in surveys, investigations and preparation, and large amount of capital investment. A more satisfactory and expeditious way would be to work the plan in stages in such a way that each stage can function as an independent project and yet become an integral part of the unified basin-wide plan. Coupled with this consideration is the urgent need for irrigation in Sambalpur district, power all over the province for industrial development, flood control in the delta, and navigation facilities to the maximum extent possible.

The above needs can be fully met by the construction of three dams on the main river, at the only three available good sites, namely Hirakud, Tikarpara (Barmul Pass) and Naraj. Each of these three projects is capable of independent development without prejudicing or being prejudiced by the construction of any other part of the unified basin wide plan and is further capable of forming an integral part of that plan.

The salient features of the Hirakud, Tikarpara and Naraj projects as well as the potential developments from each individually or in combination with one or both of the other projects are given in Table II on page 15.

HIRAKUD DAM PROJECT

It is proposed to proceed with the construction of the Hirakud dam project first. This is absolutely essential and unavoidable. It is from the Hirakud dam only that irrigation can be provided to the areas in Sambalpur district. From this one dam alone, it will be possible to afford a substantial and adequate measure of flood protection to the delta at relatively small cost and a fairly early date. Power can be developed to the extent of 350,000 k.w. so that industrial and agricultural developments can be planned and proceeded with almost at once. The regulated releases of water from the Hirakud reservoir will permit appreciable improvement in the navigability of the Mahanadi.

The construction of the Hirakud dam will, by judicious regulation of the river supplies, very materially facilitate the construction of the dam at Tikarpara, if and when taken up

It will be as well to make it clear that, although the optimum development of the Mahanadi valley for multi-purpose uses of industry, agriculture and transport during peace and war, can be secured only if all the three proposed dams are constructed, the Hirakud dam project can be constructed and operated as an independent project and that its construction will not in any way imply any commitment as to the construction of the Tikarpara or the Naraj projects. If, however one or both of the lower two projects are constructed, the Hirakud dam project will fit in as an integral unit of the overall development.

TIKARPARA (BARMUL PASS) DAM PROJECT

From what has been stated above, it follows that the construction of the Tikarpara dam is not in any way linked up with the construction of the Hirakud dam. But its consideration is necessary in the interest of the optimum development of the Mahanadi valley. This project is mentioned here merely to draw attention to its vast potentialities.

The Tikarpara gorge affords a dam site which is unique in the world. With a dam 330 ft. above low water level or 359 ft. above deepest river bed (reservoir level R.L. 500.00) it will be possible to store 109.68 m.a.ft. which is one and a half times the total mean annual run-off of the Mahanadi (73.4 m.a. ft.) at this place. With the entire run-off of the river stored, there will obviously be no further flood problem. There is no known place in the world with such wonderful storage possibilities.

With one single dam here it will be possible to generate $2\frac{1}{2}$ million k.w. of electrical power (60 per cent. load factor) which will be more than the total generation from the 26 dams of the T.V.A. put together and greater than the biggest existing power station in the world at the Grand Coulee Dam with an installed capacity of 1.8 million k.w.

The area of submergence at reservoir level 500.00 will, however, be as much as 1,825 sq. miles or 1,168,000 acres. A more modest though still very ambitious development would be to restrict the reservoir level to R.L. 430.00 giving a gross storage capacity of 47.17 m.a. ft. and maximum power development of 1.85 million k.w. This reservoir level will not interfere with the tail-race water levels of the lower power house at Hirakud. This alternative will equally completely solve the entire flood problem, but the area submerged will still be 1,004 sq. miles or 642,560 acres. Another but not quite so satisfactory an alternative would be to construct the dam to a still lower height restricting the reservoir level to R.L. 350.0. In this case the gross storage will be 13.76 m.a. ft., submergence 350 sq. miles or 224,000 acres and the power generation about 432,000 k.w.

The investigations at this site are yet in the preliminary stage and no detailed economical studies have been made. These latter are now in progress.

Like the Hirakud, the Tikarpara dam project can also be constructed as a self-supporting independent unit, but can be later integrated with the unified basin-wide plan.

NARAJ DAM PROJECT

As will be seen from an examination of Table II the Naraj dam project cannot stand as an independent unit. Without the construction of the Hirakud and Tikarpara dams, the construction of the Naraj dam will not be an economical proposition and the measure of flood protection to the delta will be inadequate. The magnitude of power development will be no more than 107,000 k.w., which is small in relation to the expense involved and the extent of areas submerged.

The prospects of this project will, however, be considerably improved if linked with the Hirakud dam project. If both the Hirakud and Tikarpara dam projects are constructed, the prospects of the Naraj dam project will be improved still further. If the Tikarpara dam is constructed to an adequate height, the construction of the Naraj dam can be held in abeyance, for a long time—at least till such time as the total power load of the valley does not exceed 2 million k.w.

Investigations at this site are in the preliminary stage. No detailed economic studies have been made, but these are being now undertaken

TRIBUTARY DEVELOPMENTS

In addition to the irrigation, power, navigation and other facilities envisaged on the construction of the three major dams across the Mahanadi, namely, the Hirakud, Tikarpara and Naraj, there will be considerable scope for similar developments on the Major tributaries of the Mahanadi in Orissa, the Eastern States and the Central Provinces and also on the Mahanadi itself higher up in the Central Provinces. These possibilities are also under investigation but do not affect the unified basin-wide plan envisaged at present.

GENERAL

The Government of the Central Provinces and Berar are contemplating the development of the head reaches of the Mahanadi in their territory by the construction of one or more dams on the main river or its tributaries. The Hirakud dam will store only a part of the available supply of the Mahanadi river, the remaining part of which will be available for conservation and utilisation in the Central Provinces. The construction of one or more dams in the Central Provinces will improve the power possibilities at Hirakud and if and when constructed at the Tikarpara and Naraj dams. With proper planning of these upper dams, it will be possible to extend into the Central Provinces the navigation facilities, made available lower down by the construction of the Hirakud dam.

TABLE II.

Items		Hirakud.	Tikarpara				Naraj.
Top R. L. of Dam.		625.0	350 0	430 0	450.0	500 0	150 0
Catchment area, sq miles		32,200	48,000	48,000	48,000	48,000	51,000
Mean annual rainfall inches		56.88	55.85	55.85	55.85	55.85	53.17
Annual run-off.	{ Maximum m.a.ft. .	69.90	102.72	102.72	102.72	102.72	103.67
	{ Mean m.a.ft.	50.00	73.37	73.37	73.37	73.37	74.05
	{ Minimum m.a.ft. ..	20.61	30.09	30.09	30.09	30.09	30.37
Annual Discharge	{ Maximum Cusecs ..	95,000	140,000	140,000	140,000	140,000	141,000
	{ Mean Cusecs .	68,000	100,000	100,000	100,000	100,000	101,000
	{ Minimum Cusecs	28,000	41,000	41,000	41,000	41,000	42,000
Minimum discharge of river, Cusecs ..		900	1350	1350	1350	1350	1500
Maximum flood discharge, Cusecs .		942,000	1,270,000	1,270,000	1,270,000	1,270,000	1,571,000
River bed level above M.S.L. ..		492.53	140.67	140.67	140.67	140.67	41.02
Low water level above M.S.L. .		503.00	168.47	168.47	168.47	168.47	68.62
Maximum flood level above M.S.L. ..		535.0	205.25	205.25	205.25	205.25	101.96
Height of the dam above deepest bed, ft.		132.0	209.0	289.0	309.0	359.0	109.0
Gross storage in m. a. ft. ..		5.30	13.76	47.17	61.28	109.68	6.83
Dead storage in m. a. ft. ..		1.20	5.76	13.76	13.76	13.76	2.93
Live storage in m. a. ft. ..		4.10	8.00	33.41	47.52	95.92	3.90
Irrigation	{ Quantity for m. a. ft. ..	3.63	3.60	3.60	3.60	3.60	3.50
	{ Area for Acres ..	1,100,000	1,100,000	1,100,000	1,100,000	1,100,000	1,100,000
Area submerged. Acres/Sq. miles ..		135,000	224,000	642,560	768,000	1,168,000	192,000
Peak hydro power developed at 60% Load Factor			350	1004	1200	1825	300
		300,000	432,000	1,850,000	2,333,000	2,500,000	(i) 107,000 (ii) 162,500 (iii) 275,000 (iv) 775,000 (v) 910,000 (vi) 910,000
Minimum regulated discharge below dam after construction of.....							
(for a mean year) Cusecs ..		8,800	28,800	88,800	100,000	100,000	(i) 12,800 (ii) 19,500 (iii) 33,000 (iv) 93,000 (v) 100,000 (vi) 100,000

(i) If Naraj alone is constructed.

(ii) If Naraj and Hirakud are constructed.

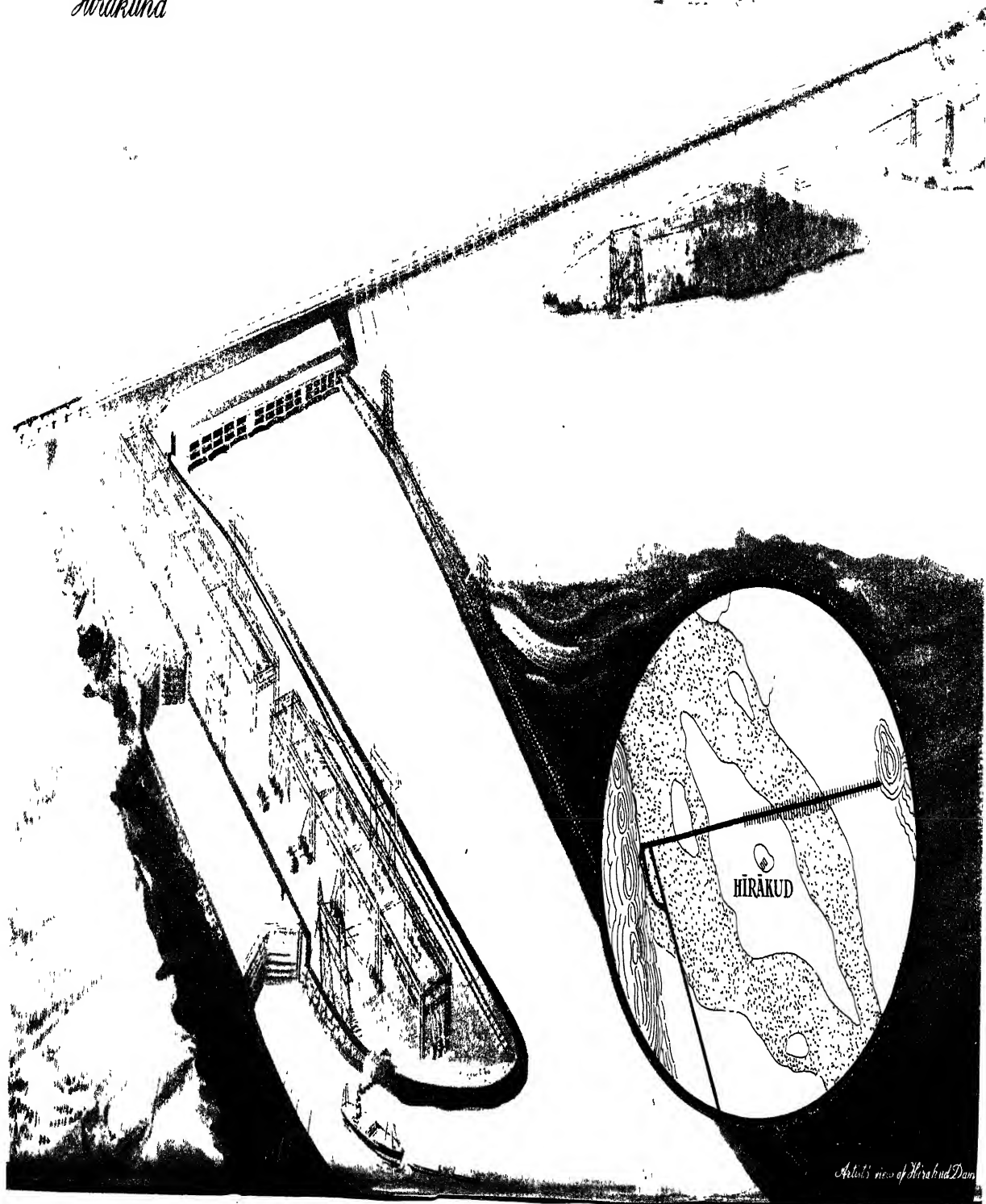
(iii) If Naraj, Hirakud and Tikarpara with reservoir level at 350 are constructed.

(iv) If Naraj, Hirakud and Tikarpara with reservoir level at 430 are constructed.

(v) If Naraj, Hirakud and Tikarpara with reservoir level at 450 are constructed.

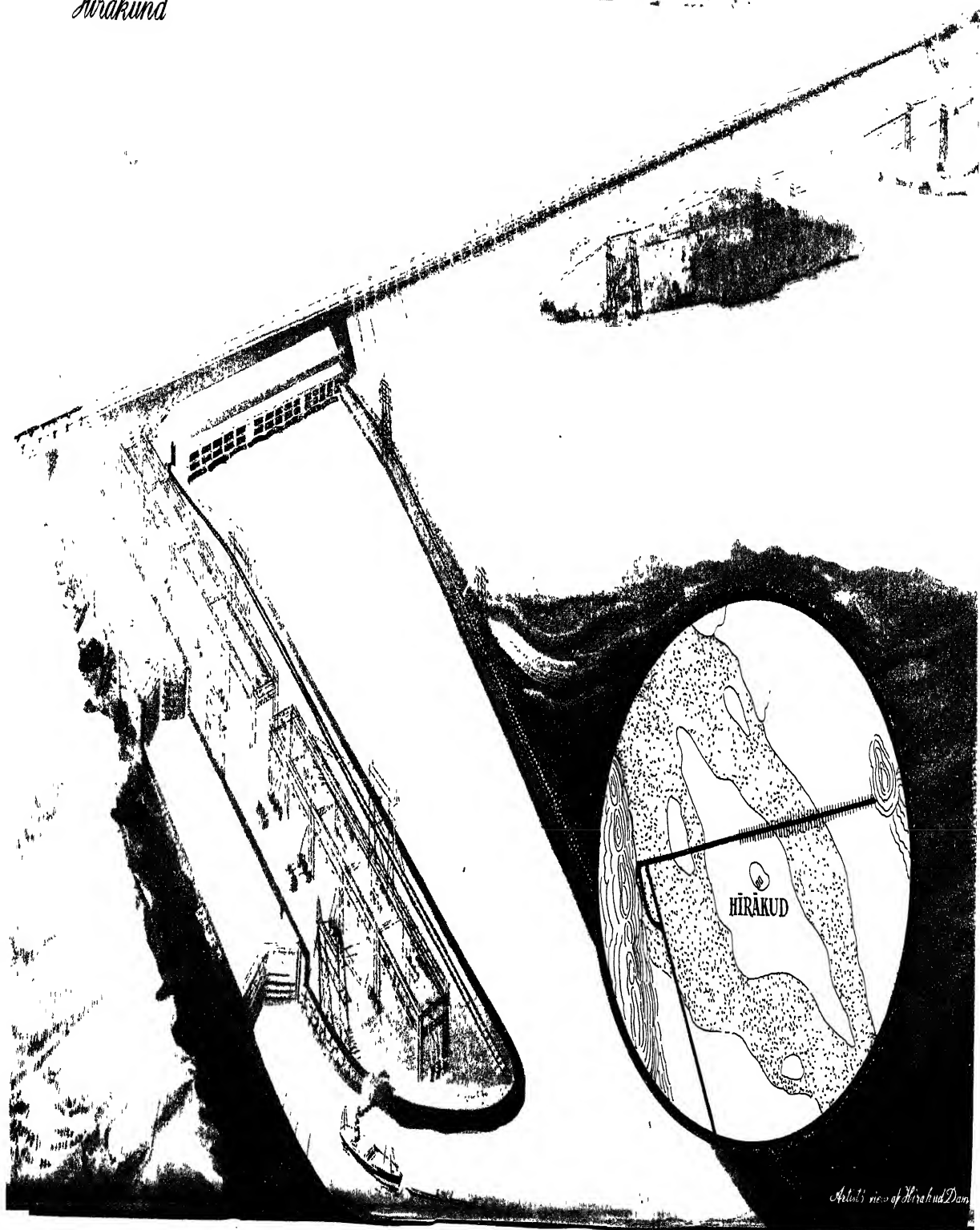
(vi) If Naraj, Hirakud and Tikarpara with reservoir level at 500 are constructed.

Hirākund



Artists view of Hirakund Dam

Hirakund



Artist's view of Hirakund Dam

CHAPTER III.

HIRAKUD DAM PROJECT.

In the context of the unified basin-wide plan and in the interest of irrigation, power generation and navigation, the construction of the Hirakud Dam is absolutely necessary as a first stage of the Mahanadi Valley Development. The Project, as envisaged in this report, can operate independently of the other units of the unified basin-wide plan and also fit in as an integral part of that plan at each successive stage.

With the construction of a dam at Tikarpara to an adequate height it would be possible to postpone for an indefinite period of time the construction of the Naraj Dam as all the irrigation, power and navigation facilities meant to be provided from the Naraj Dam could be mostly done from the Tikarpara. But that is not the case with the Hirakud Dam, which must be constructed to provide irrigation to areas in Sambalpur, to extend navigation in Sambalpur district and on to the Central Provinces, and to generate power at a strategic location at an early date.

The submergence of land is unavoidable in any scheme for the conservation and utilisation of water. In the case of the Hirakud Dam this submergence is 135,000 acres and is very considerably less than that on the Tikarpara or the Naraj Dam.

The construction of the Hirakud Dam Project has some natural advantages which are absent in the case of the lower two dams. The submerged area of the reservoir is exclusively in Orissa. Unlimited quantities of limestone and coal for the manufacture of cement (cement constitutes a major proportion of the cost of the dam) are available within 30 miles of the dam site. The site is within 9 miles of the broad-gauge rail head at Sambalpur. A service road passes through the dam site and reservoir area. Because of facilities of communications and presence of mineral deposits like iron, manganese, bauxite and limestone in the vicinity, it would be feasible to set up in the neighbourhood, ferro-alloys, aluminium, cement and other factories.

The geology of the dam site is simple and free from any complex features. The foundation rock is sound and strong. Construction materials, *viz.*, cement, (limestone, shales and coal), aggregates and sands for the concrete part of the dam and suitable earth materials for the earthen portion of the dam and dykes are available near the site.

In view of the above and the fact that the construction of this project will give adequate flood protection to the delta and provide irrigation to 1.1 million acres and a large block of power for the early development of industries, it is proposed to undertake the construction of this project immediately as an independent unit. If and when it materialises this will constitute the first unit of that plan, ~~when it materialises later on.~~

DESCRIPTION OF THE PROJECT.

Dam

The Hirakud dam structure will consist of a dam across the main channel 15,700 ft. long of which 5,000 ft. will be of concrete and the remainder of rolled rocks and earthfill. Out of the concrete portion a length of 3,880 ft. will constitute the spillway, 500 feet will house the penstocks for the power house

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and 250 feet will protect the switch yard in the rear. At the extreme right end of the masonry part of the dam there will be a navigation lock. The top of the dam and the roadway will be 642.2 throughout. The maximum height of the dam above deepest bed will be about 150 feet.

The spillway section of the dam has been provisionally shown as 3,880 ft. The actual length will depend upon the type of spillway used. Various types are under consideration. One alternative, which appears to be the simplest and possibly most economical, is to install a series of Ganesh-Iyer-Volute Siphons. These can deal with flood discharges to any extent and have the further advantage of drawing water from the bottom of the reservoir and of permitting regulation of spills without the use of any gate structure whatsoever. The other alternatives are to allow the water to spill over the top of the dam and obtain the necessary regulation of flow and control of pond levels by means of drum-gates, sector gates or stoney gates. In these latter, necessary provision will have to be made for the dissipation of energy of falling water by the construction of a bucket or a hydraulic jump structure, at the toe of the spillway section of the dam. Large-scale model tests will be shortly undertaken in connection with these alternatives.

The earthen part of the dam which will be nearly 10,700 ft. long, will have a slope of 1 : 3 on the upstream and 1 : 2 on the downstream face. The dam will have a central impervious zone with semi-pervious and pervious zones on either side. Both the front and rear slopes will be protected with stone rip-rap. The impervious zone will be carried down to hard rock or as an alternative sheet pile cut-offs going down to hard rock will be provided.

The earthen dykes on either side of the main dam, which will be 34,500 ft. in length on the right bank, and 27,000 ft. on the left bank will be of similar design as the main earth dam.

Reservoir

The reservoir formed by the dam will rise to R.L. 625.0 at which it will submerge an area of 135,000 acres. It will have a gross storage capacity of 5.3 m.a. ft. of which 1.2 m.a. ft. will constitute dead storage to provide silt reserve for over one hundred years and a minimum working head for power generation. The live storage of 4.10 m.a. ft. will provide 1.30 m.a. ft. for purposes of irrigation and by judicious reservoir regulation 2.72 m.a. ft. for flood control. Provision has been made for a further flood reserve of 0.70 m.a. ft. (or 3.42 m.a. ft. in all) five feet above the normal reservoir level. This may have to be used possibly once in a century.

Irrigation

The project provides for the irrigation of 1,094,953 acres of land, of which 619,035 acres will be by flow and 475,918 acres by lift. Out of this about 880,000 acres will be in Sambalpur District in Orissa and the rest in Sonepur State. Two main canals will take off on the right and two on the left of which one on each side will be for lift irrigation. A third lift irrigation canal will be constructed to irrigate the area north of the reservoir between the Mahanadi and Ib rivers. The full supply discharges of the canals on the right will be 2,013 cusecs gravity and 2,920 lift ; on the left 1,287 cusecs gravity and 737 cusecs lift : on the north 167 cusecs lift. The lifts will vary between 50 and 150 ft. Besides the above, another irrigation canal with a capacity of 1,676 cusecs will take off from the subsidiary reservoir upstream of the lower power house, and will irrigate the low areas on the right bank of the river.

MAHANADI VALLEY DEVELOPMENT

HIRAKUD DAM PROJECT

Showing Dam, Power House, Power Canal & Navigation Locks.
Scale : 2"=1 mile (approx)



The gross command area, the irrigable area and the maximum discharge of each canal are given in the following statement :—

Name of canals.	Gross commanded area.	Irrigable area.	Discharge.
	Acres.	Acres.	Cusecs.
Left side lift canal	110,000	73,300	737
Left side flow canal	192,000	128,000	1,287
Irrigation channel from Power channel	250,000	166,710	1,616
Right side flow canal	300,000	200,000	2,013
Right side lift canal	436,000	290,500	2,920
Foreshore channel	25,000	16,700	167

A net-work of distributaries will take off from these canals and all the cultivable area below the dam site on both sides of the river right up to the hills will be supplied with means of irrigation.

Irrigation in the Delta

Besides the 1,094,953 acres of land in Sambalpur District and Sonepur State which will receive irrigation from the Hirakud dam, the regulated supplies from the latter (ranging between 8,800 to 14,000 cusecs during the dry months against the present minimum of about 1,000 cusecs at Naraj) will provide protective irrigation to existing irrigated areas in the delta during critical periods of short supply and enable perennial irrigation to be extended to additional large areas in the delta, which cannot be brought under irrigation at present due to the likelihood of their getting submerged during floods but which will become available for irrigation as a result of the flood protection which will be afforded by the construction of the Hirakud dam. This additional irrigation may cover several lakhs of acres. The existing irrigation for the period 1935-36 to 1937-38 was 200,427 acres.

The navigability of the river made possible by the increase in minimum discharge of the river from 1,000 cusecs to over 8,800 cusecs will not be materially affected by the abstractions for the above extension of irrigation.

No credit has been taken in the project for the improvement and extension of irrigation in the delta likely to be brought about by the construction of the Hirakud dam, as it has not so far been possible to adequately investigate the irrigation situation in that area.

A thorough enquiry into the existing irrigation in the delta, the reasons for its being non-productive and the possibilities of improvement and extension seems to be urgently called for.

Power

There will be two power houses ; one at the main dam and the other 17 miles further down along the tailrace of the upper power house, to take advantage of the rapid fall of the river bed in the 25 miles reach below the dam. There will be six units of 25,000 k.w. each at the upper power house and eight similar units at the lower power house giving a total installed capacity of 350,000 k.w. The mean rated head in both cases will be nearly 85 feet. Additional space will be left in each power house for future extension to utilise any additional regulated supplies which may become available at a later date as a result of the construction of a dam or dams higher up the Mahanadi or its tributaries. In the latter case the total installed capacity at Hirakud may go up to 475,000 k.w.

The power channel from the upper power house is designed to carry a steady discharge of 18,000 cusecs, but will have a free-board of 5 ft. to provide additional capacity for the regulated supplies from the upper dams that might come later. The upper power house will be worked as a base load station and the fluctuations will be taken up at the lower power house through a subsidiary lake formed at the tail of the power channel. The tailrace from the lower power house will join the river near Dalab, 25 miles along the river below Hirakud dam.

The power generated at the dam will be used for lift irrigation to high lying areas, for industrial development at Sambalpur and elsewhere in Orissa and for domestic purposes. Some power may also be available for use of industries outside Orissa.

The Hirakud power plant will be linked in grid with the Machkund, Rihand, Kosi and Damodar hydro stations and also connected to the Jamshedpur and (proposed) Nagpur Steam stations. A high tension line will be carried to Cuttack.

Flood Control

The Hirakud dam will provide adequate flood protection to the delta from all but extraordinary floods. The additional reserve of 5 feet will afford almost complete protection even for floods of the magnitude of that of 1834.

Navigation

Two sets of navigation locks with a lift of 110 feet each will, in conjunction with the power canal, subsidiary reservoir and tailrace, provide navigation link between the river at Dalab and the Hirakud reservoir. The dimensions of lock channels are under consideration, but these may be 60 ft. \times 360 ft. The power canal and tail-race will have a depth of nearly 17 ft. With suitable blasting in some reaches and river conservancy measures in other reaches, the river between Dalab and Dholpur 84 miles downstream may be made navigable by river craft carrying 600 to 800 tons and for large towys of several such units from Dholpur to the Port of Chaudhali.

General

The Hirakud Dam Project will thus afford fairly adequate flood protection to the delta area, provide irrigation to nearly 1.1 million acres which will in turn produce 340,000 tons of additional food grains; provide power to the extent of 350,000 k.w. and with certain subsidiary works and improvements in the river lower down, provide improved navigation facilities from the sea to the Hirakud reservoir, a distance of nearly 322 miles; it will also provide facilities for fish culture, drainage, malaria control, afforestation, soil conservation and recreation. In addition it will make it possible to effect improvements in existing irrigation and to extend perennial irrigation to large areas in the delta.

Costs

The project is estimated to cost :—

(1) Dam and appurtenant works	..	..	16.16 crores.
(2) Main canal, branches, distributaries and water courses	..	..	7.80 crores.
(3) Hydro-electric installation	..	..	22.85 crores.
(4) Navigation	..	..	1.00 crores.
			<hr/>
			47.81 crores.

CHAPTER IV.

SURVEYS AND INVESTIGATIONS.

TOPOGRAPHICAL SURVEYS

The entire work of topographical and contour survey of the dam sites, reservoir areas and areas to be irrigated, is being done by the Survey of India Department by a combination of aerial and ground survey methods. The detailed surveys of the dam sites as well as the survey and location of irrigation and drainage channels, communications, etc., are being done by the staff of the Central Waterways, Irrigation and Navigation Commission.

The survey tasks for the Mahanadi Valley Development scheme allotted to Survey of India and the up-to-date progress of work are given in the following table :—

Task.	Scale.	Survey up to R.L.	Contour interval	Total area in sq miles.	Stage of photography.	Date of commencement of survey.	Estimated date of completion of survey.
Hirakud Dam .	16"=1 mile	$\frac{1}{2}$ mile N & S of dam and up to ridge on E & W.	10 ft	7 8	Completed	1-4-46	Completed.
Hirakud reservoir	4"=1 mile	650	10 ft	400	Incomplete	1-3-46	15-6-47
Irrigation area Hirakud Project.	Do.	..	1 ft.	2155	Complete except for small extension.	Nov. 46	March 49.
Tikarpara Dam .	16"=1 mile	550	10 ft.	0.93	Complete	17-11-46	10-7-47
Tikarpara reservoir	4"=1 mile	500	10 ft.	2175	In hand	Oct 47	Dec. 49.
Naraj Dam .	16"=1 mile	200	5 ft.	2 6	Complete	23-2-46	Complete.
Naraj reservoir .	4"=1 mile	160	10 ft.	305	In hand	Jan. 48	Dec. 48.

Vertical air photo cover has or is being obtained for all areas and mapping is being carried out by air or air-cum-ground survey methods. Some dam and reservoir maps are completely air surveyed ; for others the detail is to be air surveyed and the contouring will be carried out by ground survey methods.

For the 4-in. maps of the irrigation area, the detail is being air surveyed and the generalised one foot contours having an accuracy of 0.5 ft. will be interpolated from a close network of levelled height control. The height control frame work will have an absolute accuracy of 0.2 ft.

Location of dam sites.

The location of the Hirakud, Tikarpara and Naraj dam sites was determined from a consideration of the topographical features supplemented subsequently by geological investigations. These sites were selected by the Chairman, Central Waterways Irrigation and Navigation Commission in November 1945.

At Hirakud and Naraj there are no alternative sites, but as regards Tikarpara, the Satkosia gorge extends over a length of 9 miles and contains more than one dam site. The lowest site in the gorge, which is also the narrowest

and geologically the best has been selected. Below this site the gorge opens out into a valley. There will thus be no difficulty in suitably aligning the off-taking canals, and plenty of space will be available for the location of construction plant and buildings.

The geology of the three dam sites has been investigated at various times by the officers of the Geological Survey of India. These reports are given in Appendix II.

GEOLOGY OF THE HIRAKUD DAM SITE.

On geological considerations the site at Hirakud has been found to be quite sound for the construction of a dam. The floor of the valley is made of hard granite-gneiss containing a few narrow bands of mica schists, foliated in the direction N. W.—S. E. and dipping steeply either, to the S. W. or to the N. E.

The proposed dam will run obliquely across the direction of foliation, but, as both the rocks and the foliation planes are impervious to water, there is no fear of seepage due to the obliquity of the dam.

Two sets of joints are present, one running N 65°W and dipping at an angle of 62° to the S. W. and another running N 30°E and dipping 78° N. W. Most of these joints are superficial and are not expected to run very deep, and in any case the jointed surface layer will be stripped and the rock underneath grouted with cement, where necessary.

Near the edge of the river bed on the right, about 50 yards from the base of the right abutment, olive green phyllites occur, which are intruded by granitic gneisses. These phyllites gradually merge into gneisses towards the east. The exposure of phyllites and the transitional zone together is about 100 ft. wide along the centre line of the proposed dam. On the exposed surface the phyllites are relatively soft and weathered. This part of the river bed will need further exploration to ascertain the depth of the decomposition and also the nature of the relationship of the phyllites with the gneisses on one hand, and with the quartzites forming the right abutment on the other.

The right abutment is formed by a narrow N. S. running ridge made of massive quartzites. These quartzites overlie the foliated gneisses and schists exposed in the bed of the river, but the nature of their contact is concealed by talus. Work is in progress at present to expose this contact between the quartzites and the gneisses, and also to expose a section of the quartzites along the face of the abutment.

The hill mass forming the left abutment is composed of silicified rocks which appear to have resulted from an impregnation of silica solution through a fault or a shear zone. The original rock head was probably mica schists or granite-gneisses or both, but silica has so penetrated all cracks and crevices and cemented the broken rock together that now it is a solid mass or rock which is more resistant to weathering than the gneisses and schists occurring in the surrounding areas.

Fresh rock is exposed in the flood channels of the valley, and in between the flood channels the bed rock occurs at shallow depths. On parts of the Hirakud island, however, decomposition of the bed rock has proceeded fairly deep, as revealed by some of the test pits, but within the island hammocks of fresh rock protrude through the soil surface here and there, indicating that the distribution of the fresh and of the decomposed rocks is patchy in character. Similarly in the area lying between the silicious rocks forming the left abutment and the nearest flood channel on that end of the proposed dam, there are alternate patches of deep decomposition and fresh rocks.

The site was examined geologically by Mr. K. K. Dutta of Geological Survey of India, in December 1945 and by Dr. F. A. Nickell, the American Geologist, in April 1946, and more recently by Messrs. V. P. Sondhi, Superintending Geologist, A. G. Jhingran, Geologist and V. S. Krishnaswamy, Assistant Geologist of the Geological Survey. The geological reports of these officers will be found in Appendix II, parts (i) to (iii). The site was visited for the second time by Dr. F. A. Nickell, Consulting Geologist, between 25th and 28th March 1947. His conclusions are as follows :—

- (1) Extremely hard bedrock composed chiefly of granite gneiss with schist forms the foundation for the concrete section and is near the surface over much of the area.
- (2) Ample materials for construction are available including embankment materials for several types and gneiss or perhaps quartzite for crushed aggregate.
- (3) At no place will it be difficult to secure a tight cut-off or actual contact on rock to prevent seepage from the reservoir.
- (4) The foundation for all component parts of the dam is adequate with reasonable preparation, and entirely stable under load of a properly designed dam.
- (5) Conditions for low auxiliary dykes on both sides of the dam present no important problems.
- (6) Cement can be readily manufactured for the project and for commercial demand. Abundant limestone, coal and other necessary raw materials occur within a radius of 50 miles of Sambalpur.
- (7) No important loss of known mineral wealth will take place by flooding reservoir area.

Mineral occurrences of the Hirakud reservoir area.

The mineral occurrences of the area were investigated by Mr. V. S. Krishnaswamy, Assistant Geologist, Geological Survey of India and later by Dr. F. A. Nickell, Consulting Geologist. Their reports are in Appendix II, parts (v) and (vi).

Coal.

Along the Ib river coal bearing Barakars are met with near Rampur only. The formations outcropping further downstream being Archaean and Talchar rocks do not contain coal. Along the Ib river the Hirakud reservoir would submerge a small portion of coal bearing Barakars during part of the year. These Barakars are already subject to flooding during the monsoon period under normal flow conditions. The proposed reservoir will therefore not flood any area appreciably larger than exists within the high water line during floods at present.

The concerned rocks are essentially impervious, but may allow seepage along bedding contacts restricted to a low hydraulic gradient determined by dip of beds. The channel will be covered by delta deposits of sand and silt after the reservoir is formed. This will prevent seepage into the underlying Barakar series.

Diamonds.

According to Mr. Krishnaswamy it seems reasonable to conclude that the diamonds reported in the previous centuries were washed down the river from other areas and deposited along the valleys. There are no ready means of ascertaining the existence of large deposits of diamondiferous gravels alleged to

exist underneath the water in the river channels. He examined a small deposit of gravel surrounding some of the islets near Hirakud where according to local reports diamond washing was practised in by-gone days. But these did not reveal any association of diamonds. Even now gold washing is being carried on near Hirakud but there are no authentic local reports of a diamond find for a good number of years.

According to Dr. Nickell the discovery of an occasional stone does not constitute an economic deposit; rather it symbolizes an interesting and scientific curiosity. The fact, that there has been no concerted effort to open placer workings in the area of the reservoir for diamonds which have a high market price, obviously signifies the lack of commercial value of the stream gravels. Nothing of consequence is lost by flooding of the area.

Lead and silver.

A small quartz vein carrying lead with silver was recorded many years ago on the north bank of the river a number of miles upstream from the dam site. Efforts by test pits have failed to uncover the lode which is concealed by river detritus. The occurrence apparently has not excited interest prior to the recent proposals for Hirakud Dam.

Gold.

Operations on a very small scale have been carried out by villagers with reported small returns for their efforts. While this activity is doubtless profitable to some people in time of freedom from usual work, the lack of large enterprise is again rather obvious index of the insignificant mineral loss in gold arising by flooding of the area.

Unknown minerals.

A region comprising ancient rocks including intrusive bodies but under a general alluvial cover may well contain mineralized masses. The lack of important discoveries in the reservoir area and adjoining territory is not proof of absence of deposits. However from a practical view point the uncertainty about existence of any significant deposit affords no justification for hesitation in construction of the Hirakud Dam.

Limestones.

Three limestone bodies with characteristics of natural cement are found about 30 miles northwest (upstream) from Sambalpur. One will be flooded by the Hirakud reservoir, but the accessible remaining reserves are tremendous and ample for establishment of a large cement factory for the project and commercial needs.

The Dungri deposit is the largest and the best suited for development. It contains not less than 70 million tons and may well exceed 300 million tons of limestone of suitable character.

Excepting a small portion temporarily submerged by the reservoir, the valuable limestones outcropping near the village of Dungri will not be flooded by the reservoir. The possibility of preventing even this small area from submergence is being examined.

The reservoir submerges permanently the high magnesium limestones and a horizon of argillaceous limestones outcropping in the Mahanadi river bed near Padampur. The other bands of limestones which lie within the reservoir are mostly dolomitic and are subject to flooding only during a part of the year.

Materials of construction.

The main materials of construction for the masonry part of the dam will be cement, coarse and fine aggregates and water; and for the earth part of the dam, earth materials and rock for rip-rap.

Aggregates.—Natural stream gravels are almost non-existent. The aggregate must therefore be obtained by crushing quarried rock. The Cuddapah quartzites on the right abutment and the gneisses in general will be suitable for the purpose though the latter may be better and more economical.

Sand.—The river sand is clean and consists of quartz and felspar. It is practically free from clayey impurities.

Water.—The chemical analysis of the river water (one sample collected when the river was running normal and the other during a freshet), indicates the absence of organic matter, acid, alkalis or any other deleterious constituents. This water can, therefore, be safely used for construction operations, *e.g.*, mixing and curing concrete and soil stabilisation.

Earth materials.—Impervious materials for the embankment are available in quantity in several places, but the choice is to be made on comparative results of laboratory tests when prospective stores have been explored adequately. As far as possible borrow-pits will be located in the reservoir area. The soils from a number of test pits were examined for their mechanical composition and structural properties *e.g.*, densification, shear test, etc. Table III shows the results of some of the analysis.

TABLE III.
Analyses of the soils from the test pits.

Serial No.	Sp. Gr.	Apparent density lbs. per cub. ft.	Optimum Mois- ture limit.	Max density lbs. per cub. ft.	Shear		% Clay Content.
					Tan	Cohesion	
1	2.38	93.6	11.4	127.6	0.767	135	6.7
2	2.56	99.84	12.6	129.2	0.7	190	9.5
3	2.43	90.48	12.0	125.3	0.75	108	4.4
4	2.48	99.85	12.8	121.9	0.65	167.5	4.5
5	2.33	94.85	12.2	132.0	0.8	180	6.8
6	2.37	93.60	10.2	139.0	0.725	185	5.5
7	2.42	91.33	12.8	129.8	0.925	172	16.4
8	2.49	96.09	12.6	118.2	0.75	230	5.2
9	2.35	96.29	15.6	127.0	0.967	143	21.4
10	2.49	93.60	14.2	124.2	0.7	265	6.3
11	2.36	93.61	17.2	113.0	0.733	200	23.0

Soils and rocks for building the impervious, semi-pervious and pervious sections of the earthen dam are available near the site. By a combination of soils from different borrow pits it will be possible to secure high density of the fill possibly up to 140 lbs per cubic foot.

Rock for rip-rap.—The gneiss covering the dry river channel, talus rock of quartzite particularly along the right abutment, quarried quartzite and waste from the quarry supplying the aggregate for constructional purposes are the various sources which can be tapped to provide sufficient material for

the protective rock cover on the upstream face and for the rock-fill section on the downstream side of the earth dam.

CEMENT MANUFACTURE.

As has been indicated above many deposits of limestone suitable for the manufacture of cement are available near Dungri some 30 miles from the dam site. The deposits are said to contain not less than 70 million tons and possibly over 300 million tons of limestone of suitable character. The cement requirements on the Hirakud Dam Project are not likely to exceed half a million tons.

The other raw materials for the manufacture of cement are shales, coal and gypsum. A certain amount of shale or slate may be required to be added to the natural limestone to obtain a proper ingredient for cement manufacture. Suitable shales or slates can be obtained from the shales associated with the limestone. Coal deposits exist within 30 miles of the dam site as will be seen from Plate II. The nearest working mines are at Rampur Coal Fields near Ib station. There is no recorded occurrence of gypsum anywhere in Sambalpur district. This raw material will have to be obtained from outside.

Cement forms a major part of the construction cost of the dam. A considerable portion of the cost of cement is in transport. The setting up of a factory at or near the dam site when limestone and coal are situated within easy distance will result in material savings in cost of transport. The savings on cement during the course of construction may be more than the entire cost of setting up a new factory. This cement factory will be strategically situated for the construction of the lower two dams at Tikarpara and Naraj as well as for the civil requirements of Orissa and adjoining States. With the enormous resources of the area in limestone and coal, with cheap power obtained from the dam, and with navigation facilities which will become available in an increasing measure with the construction of each new dam, the cement factory at Hirakud will be able to supply all the needs of Orissa and leave ample margin for export to Bengal, Madras and elsewhere. This factory will be an asset of great and lasting value to Orissa.

EXPLORATORY DRILL HOLES, SHAFTS, DRIFTS, ETC.

The maximum height of the Hirakud Dam above bed rock is about 150 ft. The foundation rocks are strong enough to support a dam many times that height. But in order that no zones of weakness may be allowed to remain in the foundation and to ascertain the best means of treating the zones of weakness, if any, a programme of exploratory work comprising the making of deep holes with diamond drills, and of constructing shafts and drifts has been planned and is being carried out as the necessary equipment becomes available. Geologists and specialised drill operators will be continuously at work till all the geological features of foundation rock have been fully explored.

HYDROLOGY.

Rainfall-runoff.

The subject of rainfall and runoff has been dealt with in Appendix III. Professor P. C. Mahalanobis's classical work entitled "Rain storms and river floods in Orissa" has provided most of the basic data prior to 1932 for analysing the rainfall-runoff characteristics of the river in respect of flood peaks and flood volumes. There are 39 rain gauge stations in the Mahanadi catchment area, of which 23 are above Sambalpur.

The mean annual rainfall over the Mahanadi catchment above Sambalpur for the period 1926—45 was 56.88 inches, the minimum being 39.76 inches and the maximum 67.00 inches. The respective mean minimum and

maximum runoffs have been computed as 50.00, 24.56 and 63.88 million acre-feet, respectively.

Daily observations of discharges of the Mahanadi have been started at Hirakud, Tikarpara and Naraj sites since June 1946. More gauging stations will be added as necessary.

Floods.

The magnitude of the maximum probable flood at Naraj has been assumed to be 1,570,000 cusecs which is the calculated discharge for the 1834 flood for which, however, no authentic record exists. There is no direct evidence as to the probable peak flood discharge at Sambalpur. From a study of the recorded floods, however, it appears that the probable maximum may not exceed 847,000 cusecs. In the absence of more definite information the maximum probable flood peak discharge has been computed from the Naraj peak discharge

on the basis of catchment areas as $1,570,000 \times \left(\frac{32,200}{51,000} \right)^{\frac{2}{3}} = 1,110,000$ cusecs. where 32,200

sq. miles is the catchment area above Sambalpur and 51,000 sq. miles is that above Naraj. This study will be further pursued with a view to determine the maximum probable flood in say one thousand years. For purposes of flood moderation studies, a peak discharge of 942,000 cusecs at Sambalpur and 1,570,000 cusecs at Naraj have been accepted.

A statement of all high floods in the Mahanadi at Naraj since 1867—highest that occurred each month each year—is given in Appendix III and plotted on Plate XI. The question of flood frequencies has been dealt with at some length in Professor Mahalanobis's book referred to above.

Silt surveys.—With a view to determine factually the probable rate of silting of the proposed Hirakud and other reservoirs, daily analysis of the Mahanadi waters to find their silt content in different parts of the year have been started at Sambalpur, Tikarpara and Naraj since October 1946. This work will continue for several years but some definite indication as to the actual annual silt charge of the river will be available by the end of 1947.

SOIL SURVEYS.

A reconnaissance soil survey of the areas to be brought under irrigation and of those set apart for the resettlement of the people dispossessed from the reservoir area has been carried out. This has been dealt with in Appendix IV.

A detailed soil survey of these areas is now being undertaken.

FOREST SURVEY.

A reconnaissance forest survey of the Mahanadi Valley and more particularly of the Hirakud Project areas has been carried out and is dealt with in Appendix XI. This survey has a twofold purpose, firstly commercial and industrial and secondly soil conservation for minimising the silt load of the Mahanadi and its tributaries. Detailed studies will be undertaken at an early date.

MALARIA SURVEY.

A special officer from the malaria survey of India is being deputed to carry out the malaria survey of the Hirakud Dam Project area in particular and the entire Mahanadi Valley in general. It is hoped this work will be taken up soon.

FISH SURVEYS.

A fishery specialist is being put on special duty to study the problem of fish culture in the reservoir to be formed by the dam, in village ponds filled from rain or irrigation water and other hatcheries.

CHAPTER V.

RATE OF SILTING OF THE HIRAKUD RESERVOIR.

Siltcharge of the Mahanadi.

Silt observations of the Mahanadi at Hirakud were started on 1st October 1946. The water during the period October to February has been more or less clear and the silt charge negligible. The silt charge during the monsoon months must, however, be considerable. A quantitative indication of this should become available after the 1947 monsoon, although it will take several years of observations before the mean annual silt charge of the stream can be ascertained with any degree of accuracy. In the meantime a fairly close estimate of the silt yield of the catchment of the river above Hirakud can be made on the analogy of similar catchments elsewhere in India and the world in respect of which such observations have been made over long periods.

A comprehensive paper embodying all available data on silting of reservoirs and their analysis was presented by Mr. A. N. Khosla to the Central Board of Irrigation in July 1940. Relevant extracts from this are given in Appendix V. From this analysis it was found that the annual rate of silt carried by a stream would normally not exceed 75 acre-feet per 100 square miles of catchment. On this basis the annual silt yield from 32,200 square miles of the Mahanadi catchment above Hirakud would not exceed 24,150, say 24,000 acre-feet. In this connection it may be noted that roughly 25 per cent. of the catchment area of the Mahanadi above Sambalpur is protected by reserved or zamindari forests.

Nile and Columbia rivers.

The mean annual run off of the Mahanadi at Hirakud is 50.00 million acre-feet (Plate VIII). The live storage of the reservoir above Hirakud is only 4.1 million acre-feet or nearly 8 per cent. of the mean annual run-off. The conditions are very similar to those at the Aswan Dam in Egypt and the Grand Coulee Dam in U.S.A., in both of which reservoirs there is little or no silting. The relative figures are :

				Mahanadi river at Hirakud.	Nile river at Aswan.	Columbia river at Grand Coulee dam site.
Catchment area	..	..	sq. miles	32,200	6,20,000	74,000
Mean Annual run off	..	..	(m.a.ft.)	50.00	66.00	80.00
Live storage	..	..	(m.a.ft.)	4.1	4.4	9.65
Mean annual rate of silting	..	..	(m.a.ft.)	?	0	0
Height of dam	..	..	ft.	125	175	550

The river Nile carries large volumes of silt but the reservoir is kept free from silting by passing floods through sluices at bed level and storing supplies during non-silting periods. In the case of the Columbia, the river water is said to be silt free throughout the year. The surplussing at the Grand Coulee is over the dam which is 550 ft. high.

Life of the Hirakud reservoir.

In the case of the Hirakud reservoir, provision will be made for sluices at bed level capable of carrying the bulk of the flood waters supplemented suitably by Ganesh-Iyer-Volute-Siphons which will also draw water at bed level.

(The details of spillway designs are being worked out. For purposes of estimate, however, the expensive type of over-flow spillway has been taken). The live storage being only 8 per cent. of the mean annual run-off, the total silt trapped in the reservoir with bed sluices and deep set siphons, if taken on a proportionate basis, should not exceed 8 per cent. of the total annual silt yield of the catchment or about 2,000 acre ft. The silt reserve provided in the reservoir is 1.20 m.a.ft. On the above basis the silt reserve in the reservoir would be enough to trap the silt charge for a period of 600 years, without causing any diminution in the live or usable storage. The quantity of silt annually deposited in the reservoir will, in actual practice, be much greater as, with the drop in velocities of the flood waters as they enter the reservoir, part of the heavy silt carried by these waters must settle down before it has the opportunity of being carried to the deep set sluices and siphons for discharge into the river below. On the other hand, since it is proposed to discharge floods up to 700,000 cusecs through the deep set sluices and siphons, a very substantial quantity of coarse silt and the bulk of the suspended silts must be carried with these large discharges to the river channel below the dam. During floods, the lake water will not move as a whole. The flood waters will run in one or more large size density currents and carry with them a major part of their original silt charge. As to what part of this silt charge will settle down in the reservoir, and what part will flow out with the water discharged below the dam, will remain problematic for a considerable period of time. But if it can reasonably be assumed that most of the suspended silts will be carried down and an appreciable proportion of the coarse silts will also be similarly discharged, it would appear that at least one half and possibly two thirds of the total silt charge will be so removed from the reservoir. According to this the annual silt deposit may range from 8,000 to 12,000 acre ft. per year giving the life of silt reserve as 150 and 100 years respectively, before which period the usable or live storage will remain undiminished. For purposes of the project, to be on the conservative side, this is taken as 100 years.

If and when the silt reserve fills up, the silt removing capacity of the deep set sluices and siphons will increase many times as the entire flood discharge will then have to pass at the newly formed bed level at 580 (which is top of silt reserve) and the conditions of flow similar to those at the Aswan dam will be established. The rate of silting thereafter will rapidly fall off and ultimately become too small to be of consequence. The live storage may thus continue for centuries after the dead storage or silt reserve is filled up and the dam will have covered many spans of useful economic life. In the extreme stage, which may be several centuries from now, the Hirakud dam power stations will become a run of the river station with increased working heads. But it is inconceivable that in this long interval of time, storage or check dams will not be constructed higher up the Mahanadi and its tributaries or other corrective measures taken. *e.g.*, prevention of soil erosion.

Estimated Silting of Lake Mead and preventive measures.

The usual provision for silt reserve in storage reservoirs in U.S.A. is for 40 to 50 years only. In the case of the Lake Mead formed by the Boulder dam on the Colorado, U.S.A. the silt reserve of 3,000,000 acre feet is meant to last for 50 years at 6,000 acre ft. per year against a total estimated silt charge of 137,000 acre ft. per year—the intention being to trap (137,000—60,000) 77,000 acre ft. of silt each year at a dam or dams to be constructed higher up the river. The reservoir capacity at the Boulder dam is 32,000,000 acre ft., which

is more than twice the total annual runoff of the Colorado river at the dam site so that the entire flood waters will be stored in the reservoir in the first instance and drop their silts. The releases through the outlet works will be in relatively smaller quantities and for the most part take place after the occurrence of floods. As against this the reservoir capacity at Hirakud is only 8 per cent. of the mean annual flow. In the former case most of the silt carried by floods must necessarily deposit in the reservoir and only a small part of it will be carried down through the outlet works by what is known as density currents. But before this silt reserve is allowed to be used up, the U.S. Government will build dams higher up the Colorado river and its tributaries so that the life of the reservoir can be very considerably prolonged. In the same way, long before the expiry of the period of 100 to 150 years in which the silt reserve in the Hirakud reservoir will be used up, other dams will have been constructed higher up on the Mahanadi and some of its tributaries. One or more of these dams may be constructed by the Government of the Central Provinces not long after the construction of the Hirakud dam. These dams will trap, a considerable part of the silt charge of the river, in which case the silt reserve at the Hirakud dam may suffice for a considerably longer period. The silting of this reservoir should not, therefore, give undue cause for anxiety.

Silt retention and delta formation.

Apart from the consideration of prolonging the life of the reservoir, it will be desirable, in the interest of the delta building activities of the river and the maintenance of the sea edge against the movement northwards of the silt of this edge by littoral drift, to pass below the dam, as much silt charge of the stream, as can be carried harmlessly to the sea. The flood moderation dealt with in Chapter IX and Appendix VII and the increase in water supplies brought about by the regulated releases from the dam will ensure better regime conditions of the river so that the silt will pass down to the sea without adversely affecting lands en-route or blocking the river channels.

It should be realised however that with the construction of the Tikarpara and Naraj reservoirs later on, the quantities of silt, other than that in suspension, passing in the stream below the dams will rapidly decrease. The fine fertilising silts will, however, not wholly settle down in the reservoir, and will be mainly carried to the fields with the irrigation water drawn from the reservoir. Similar silts carried down by the moderated flood flows will continue to spill with the flood water over the flood plain of the Mahanadi in the Delta and continue to add fertilising material to the lands.

CHAPTER VI.

RESERVOIR CAPACITY AND RESERVOIR LEVEL.**RUNOFF AT HIRAKUD.**

The subject of rainfall and runoff of the Mahanadi river has been dealt with in detail in Appendix III and Plates VII, VIII and IX. The catchment area of the Mahanadi above Hirakud is 32,200 sq. miles which is nearly 63 per cent of the catchment above Naraj, where the river debouches in the delta. Of this 19,500 sq. miles lie in the Central Provinces.

The mean annual rainfall over the catchment above Hirakud for the period 1926 to 1946 works out to 56.88" and the runoff 28.33", the equivalent of 50 million acre ft. This colossal volume of water should have tremendous irrigation and power potential. As to what part of this potential can be developed at Hirakud will depend on a number of considerations.

DETERMINING FACTORS.

Considering the topography of the dam site and the reservoir area, it will be possible to develop only a part of the irrigation and power potential of the flow of the Mahanadi at this site. The balance of it must necessarily be left over for development lower down the river. The storage capacity of the reservoir will be further restricted by a consideration of the cultivated areas which are likely to be submerged and the availability of land for the resettlement of the dispossessed inhabitants. The optimum reservoir capacity and reservoir level will be determined by a consideration of the requirements of flood control, irrigation, power and navigation with due regard to the extent of submergence of cultivated lands in the reservoir. The reservoir capacity will have to be examined in the context of the unified basin wide plan.

Irrigation.

The mean total quantity of water required for irrigation each year vide Appendix VI will be 3.63 m.a.ft., made up of 2.94 m.a.ft. direct from the reservoir and 0.69 m.a.ft. from the power channel. This will be mainly available from the normal flows of the river except in bad years. In 1941-42, the worst year on record the withdrawal for irrigation from storage will be 1.36 m.a.ft. inclusive of 0.36 m.a.ft. reservoir losses.

Power.

For purposes of power, the greater the reservoir capacity the more economical the development. In the case of the Hirakud dam the power potential is so great that at best only a part of it can be developed. The reservoir level and the height of dam will therefore have to be determined primarily from a consideration of purposes other than power, but the latter will mainly govern the economics of this development.

Flood Control.

The question of flood control is dealt with in detail in Chapter IX. The gauge to which the flood waters may be allowed to rise at Naraj without doing material damage is 90.0. A safer gauge would be 89.0. Flood studies indicate that it will be possible to regulate the floods of the Mahanadi by means of a storage dam at Hirakud, so that even in the abnormal floods like those of 1834, the gauge at Naraj will not exceed 90.0. This will require a live storage capacity of 3.51 m.a.ft. The storage capacity required to regulate

normal floods so that the safe gauge 89.0 at Naraj is not exceeded will be 2.72 m.a.ft.

Navigation.

Navigation depends on the amount of minimum flow during any part of the year. At present this minimum flow may be less than 1,000 cusecs and the more we can raise this minimum figure, the greater will be the possibilities of navigation. A minimum flow of 8,800 to 14,400 cusecs will afford reasonably good draft if some stream obstructions, like jutting rocks, are removed simultaneously.

Silt Reserve.

This has been dealt with in Chapter V and a silt reserve of 1.20 m.a.ft. has been assumed to be satisfactory.

RESERVOIR CAPACITY.

For the purposes of flood control the reservoir capacity should not be less than 3.51 m.a.ft. To this should be added the silt reserve so that the flood protection remains fully effective for at least one hundred years. The total reservoir capacity required for flood control will thus be

Flood reserve	..	3.51 m. a. ft.
Silt reserve	..	1.20 m. a. ft.

Total : .. 4.71 m. a. ft.

For purpose of irrigation no storage as such may be required in a normal year but storage will be necessary in bad years. In 1941-42 a reservoir capacity of 1.36 m.a.ft. inclusive of reservoir losses will be required. This added to the silt reserve of 1.20 m.a.ft. will make up a minimum reservoir capacity of 2.56 m.a.ft. See Chapter VIII, page 44.

As stated above, there is no limit to the reservoir capacity for purposes of power development. But in view of the limitation imposed on the reservoir level by a consideration of the extent of submergence and keeping in mind the minimum requirements for flood control and irrigation, the economic live storage for power works out to 3.62 m.a.ft. Allowing 0.36 m.a.ft. for reservoir losses and 1.20 m.a.ft. for silt reserve, the total storage capacity for power would be 5.18 m.a.ft.

The water drawn from storage for purposes of irrigation will on the whole, not be available for power generation, as the bulk of it is drawn direct from the reservoir, and only a small part, required for the canal off-taking from the power canal, passes through the first power house for generating power. The combined capacity required for power plus irrigation will thus be $5.18 + 1.00 = 6.18$ m.a.ft. (reservoir losses and silt reserve being already included in the figure 5.18).

If the requirements of the flood control and power or flood control and irrigation were simultaneous the capacity of the reservoir would have to be as follows :

						Flood control & power.	Flood control & Irrigation.
Flood reserve	..	..	..	..	..	3.51 m.a.ft.	3.51 m.a.ft.
Power	..	..	..	..	..	3.62 "	1.00 "
Reservoir Losses	..	..	..	..	..	0.36 "	0.36 "
Silt reserve	..	..	..	..	..	1.20 "	1.20 "
Total						8.69 m.a.ft.	6.07 m.a.ft.

Fortunately, however, after the floods are over there is enough water to fill the reservoir for purposes of power generation. From the maximum flood graph of Plate XI it will be seen that during the period 1872 to 1946, for which gauge record is available, the gauge at Naraj never exceeded 89.0 after the 24th September. Therefore the entire capacity reserved in the reservoir for flood absorption can be safely filled up after the 24th September. The hydrograph further shows that there is always more than enough water in the river in late September and throughout October to fill the reservoir even in the worst year. Thus the entire live storage capacity of the reservoir including that reserved for flood absorption will be available each year for use in irrigation and power generation. Thus the reservoir capacity required for the three purposes of flood control, irrigation and power taken together, will be 6.18 m.a.ft. Summing up, the reservoir capacity required for each purpose is :

For flood control alone	..	..	..	..	..	4.71 m.a.ft.
For Irrigation alone	..	..	...	...	..	2.56 m.a.ft.
For Power alone	.	..	...	...	..	5.18 m.a.ft.
For Irrigation plus power	..	...	...	..	...	6.18 m.a.ft.
For flood control plus Irrigation plus power	..	..	..	..	..	6.18 m.a.ft.

All things considered, the optimum capacity of reservoir will be 6.18 m.a.ft. But this will need a reservoir level of 631.00 and submerge 148,500 acres of land. Such large submergence in this case would be undesirable. A compromise has therefore to be made between the requirement of multi-purpose development and the necessity for keeping the extent of submergence as low as possible. The lower limit of capacity will be the minimum capacity required for flood control i.e., 4.71 m.a.ft and the optimum 6.18 m.a.ft. It is proposed to limit the gross capacity to 5.3 m.a.ft. which will afford full protection against all but abnormal floods and provide for nearly all irrigation and power generation except in bad years when the normal flow of the river is very poor. For protection against abnormal floods, an additional storage capacity which may be used once in a hundred years or so will be necessary.

With the amount of storage envisaged above, it will be possible to pass a minimum regulated flow of 8,800 cusecs, which will greatly improve navigation possibilities below Hiralud. This aspect has been dealt with in Chapter XII.

HEIGHT OF DAM.

For a reservoir capacity of 5.30 m.a.ft. a reservoir level of 625 is necessary. The capacity statement is given in Table IV and the area capacity curves for different reservoir levels are in Plate X.

The reservoir level for purposes of flood control, power, irrigation and navigation will be restricted to 625, and for abnormal floods like those of 1872 and 1834 this level will be permitted to rise, up to 630.5; but as explained in Chapter IX, the reservoir level will stay above R.L. 625.0 for a maximum period of 5 to 6 days only.

SUMMARY OF DESIGN FEATURES.

The following is a summary of the design features :

Reservoir level	..	..	..	..		625.0	
Reservoir Capacity	..	..	..	..		5.30 m.a.ft.	
Flood reserve ..	..	..	..	..	600.0 to 630.5	3.51	„
					600.0 to 625.0	2.72	„
Live storage ..	..	..	..	..	580.0 to 625.0	4.10	„
Silt reserve or dead storage	..	..	..	..	Below 580.0	1.20	„

The annual run offs of the river at Hirakud are :

Minimum	..	..	..	..	..	1902	20.61 m.a.ft.
Maximum	..	..	..	..	..	1919	69.90 „
Mean	..	..	..	..	..	(1926-46)	50.00 „

EFFECT OF HIRAKUD RESERVOIR ON UPSTREAM DEVELOPMENTS.

The total amount of water required for irrigation each year will be 3.63 m.a.ft. made up of 2.94 m.a.ft. direct from the reservoir and 0.69 m.a.ft. from power channel. The total amount of water used for power generation will on the average be 8.74 m.a.ft. In addition there will be a mean annual reservoir loss from evaporation etc. of 0.60 m.a.ft. The total water required for irrigation and power including reservoir losses will be $2.94 + 0.60 + 8.74 = 12.28$ m.a.ft. of which 4.10 will be derived from storage and the balance from the normal flow of the river. The minimum run off of the Mahanadi at this point is 20.61 m.a.ft. If the full requirements of power and irrigation at Hirakud as proposed in the project are met, there will still be 8.33 m.a.ft. of water available in the river in the worst year for storage and diversion at dams higher up on the main river or the tributaries.

ECONOMIC STUDIES.

Detailed studies to determine the economics of the Hirakud dam for reservoir levels of 615, 625, 630 and 635 are in progress. These will also be considered in the context of the basin-wide plan dealt with in Chapter II.

The preliminary economic studies carried out so far, however, indicate that a project with reservoir level at Hirakud of R.L. 625.0 with an emergency flood reserve up to R.L. 630.5 (to be used perhaps once in a century for a period of five or six days) and a dead pond level of 580.8 will secure the most satisfactory overall results in flood protection, irrigation, power generation and navigation. This project has accordingly been prepared on this basis.

TABLE IV.

Area and Capacity of the Hirakud Reservoir at Different Levels.

R. L.	Area in acres.	Capacity M.a.ft.	R. L.	Area in acres.	Capacity M.a.ft.
631	1,48,500	6.13	605	92,000	3.07
630	1,47,000	6.00	604	90,000	2.97
629	1,44,000	5.82	603	88,000	2.87
628	1,41,000	5.66	602	86,000	2.77
627	1,39,000	5.54	601	84,500	2.67
626	1,37,000	5.42	600	82,500	2.58
625	1,35,000	5.30	599	80,500	2.49
624	1,32,500	5.20	598	78,500	2.41
623	1,30,500	5.10	597	76,500	2.33
622	1,28,000	4.99	596	74,000	2.24
621	1,26,000	4.87	595	72,000	2.16
620	1,23,500	4.75	594	70,000	2.08
619	1,21,500	4.63	593	68,000	2.00
618	1,20,000	4.51	592	66,000	1.92
617	1,18,000	4.38	591	64,500	1.84
616	1,16,000	4.25	590	63,000	1.77
615	1,13,500	4.12	589	61,000	1.70
614	1,11,000	4.00	588	59,500	1.64
613	1,09,500	3.90	587	58,000	1.58
612	1,08,000	3.80	586	56,000	1.52
611	1,06,000	3.69	585	54,500	1.46
610	1,04,000	3.58	584	53,000	1.41
609	1,02,000	3.47	583	51,500	1.36
608	99,000	3.37	582	49,000	1.31
607	96,000	3.27	581	48,000	1.25
606	93,500	3.17	580	47,500	1.20

CHAPTER VII.

AREA SUBMERGED, COMPENSATION AND RESETTLEMENT.**AREA SUBMERGED.**

The area submerged under the proposed Hirakud reservoir, with reservoir level at 625.00 will be 135,000 acres out of which nearly 70,000 acres will be cultivated land.

The contour survey of the reservoir area has been completed by the Survey of India Department, but the printing up of the sheets has not been completed. It has, therefore, not been possible to locate the submerged area on the village maps nor to work out the detailed figures of compensation.

There is considerable agitation in the area against the submergence of lands. This is natural, but no major storage project can be constructed without submerging considerable areas of land. On the proposed Rihand (Sone) Dam Project in the United Provinces, Tungabhadra Project in Madras, and Hyderabad, and the Damodar Valley Project in Bihar and Bengal, nearly 200 square miles will be submerged in each case. On the Ramapadasagar Project in Madras nearly 500 square miles will be submerged.

On the Norris dam—one of the 16 new dams constructed by the T.V.A.—141,700 acres of cultivable land were acquired for the reservoir area, and 2,899 families resettled at an overall cost of Rs. 2.55 crores. "Some (families) were antagonistic towards the Authority's programme Some of the largest property owners felt that Government was forcing them out of their rightful homes for a new civilisation in which they had no interest. . . . A small group of them considered the possibility of leaving the United States and establish a new colony in Brazil. Efforts to persuade some of the families to relocate in lower and more productive land or in other sections met with little success—the mountain families did not want to become 'low landers'". (Pages 503-4 & 5. The Norris Project-1940). It may be mentioned in passing, that these very objectors are now among the ardent supporters of the T.V.A.

COMPENSATION.

A most useful note on the subject of compensation has been furnished by Mr. R. S. Swann, I.C.S., Deputy Commissioner, Sambalpur, *vide* Appendix XIII. This note deals with the classification of lands, the rights of Gountias and the basis for and the difficulties in the way of the assessment of compensation for land, property and other rights. Compensation based on the record of rentals, mutations and transfer of leases would appear to be inadequate for the purpose. The present market values must be given due consideration. Compensation should be equitable and even generous. Land should be given for land as far as possible and the dispossessed inhabitants settling on new lands helped and encouraged to construct and live in model villages with provision for incorporating modern amenities in due course.

Mr. Swann has roughly worked out a figure of Rs. 5,60,62,635 for compensation. Out of this he has shown Rs. 50,90,650 as creditable to Government for its various rights. As it was not possible to collect the detailed data in time, the estimate is admittedly rough, but it affords a useful indication. While his

figures, though generous, may be more or less accepted in respect of compensation to the dispossessed people, they cannot be accepted as regards compensation to Government. For purposes of the project all Government wastes and Government rights should be made over to the project at a nominal value. In the case of Crown lands in the Punjab (and it is believed elsewhere too) this value is taken at Rs. 10 per acre.

Since considerable areas of forest land, the bulk of which are non-productive at present, will be reclaimed, provided with irrigation, and given to the dispossessed people in exchange for their submerged lands, it is reasonable to assume that considerable saving in the cost of compensation as given by the Deputy Commissioner may be anticipated. A lump sum provision in the project of Rs. 5 crores for compensation would, under the circumstances, appear to be conservative. A further provision of 5 per cent. for establishment on compensation will increase this figure to Rs. 5,25,00,000.

While consideration of public good must have precedence over that of private interests, the latter must be fully and even generously compensated if, in the public interest, these interests have to be acquired by the State.

AREAS AVAILABLE FOR DEVELOPMENT.

It is understood that about 50 per cent. of the dispossessed people will have to be provided with land. From a preliminary investigation of the areas available for resettlement, it has been possible to locate about 106,400 acres for the purpose, as shown below:

			acres	
Barra Jungle	..	..	62,800	
Village Forest	..	..	12,300	
Govt. Reserve Forest	..	..	17,000	Original figure given by Deputy Commissioner, Sambalpur was 9200. It has been since revised to 17,000 and there is the possibility of still further areas being added.
Zamindari Forest	..	..	7,500	
Gochar lands	..	..	6,800	
			<hr/>	
			106,400	

A considerable area of Government reserve forests lies on either side of the Ib river. It is proposed to provide lift irrigation for the whole of this area. From the soil investigation carried out so far, the lands in this area appear to be very suitable for agriculture. The introduction of irrigation to this area, would make it productive of good crops, as, because of the forest cover, the nutrient soil constituents have been preserved and soil erosion prevented.

In addition to the forest lands there will be 20,000 to 40,000 acres of marginal lands which will reappear each year with the depletion of the reservoir, and, with the newly laid rich silt deposits and moisture retained from the reservoir, will be available for raising one good crop from March to September (*vide* Chapter X). It is possible that the cultivators whose villages are only partly submerged might prefer to make use of these marginal lands instead of moving to new areas.

A third possibility is for the Government to acquire areas in different Zamindaris which are lying waste at present and which can be brought under cultivation on the introduction of irrigation.

POLICY OF ACQUISITION AND RESETTLEMENT.

It is hoped that more than the required area of land will be available from Government and zamindari forests, the marginal lands, and acquired waste lands. Government should, however, consider the question of acquiring proportionate areas of land from those who will be benefited from the project by irrigation and otherwise and in this way minimise the hardship of land acquisition by spreading it over a wider section of the community. According to this, each land owner holding lands above a certain economic minimum may be required to give to Government on payment of compensation a part of his land, which will bear the same proportion to his total holding as the area required for the reservoir, canals and connected works on the project will bear to the total area to be benefited by the project. Such areas will necessarily be in fragments but they can be consolidated into compact blocks by readjustment between the various holders and then used for the resettlement of the dispossessed people.

This form of land compensation has been tried with success in other projects, *e.g.*, Krishnarajasagara Dam and Reservoir Project in Mysore State. Experience had shown that paying money compensation to owners of land and the Government taking no steps to resettle them would, in a majority of cases, reduce such owners to the status of landless labourers. So the Government of Mysore built 25 new villages in place of those which were submerged, arranged irrigation facilities for the available Government waste areas and acquired from the holders of land of 3 acres and above (which were to receive the benefit of irrigation) about 33 per cent. of their holdings in cash compensation. The area so acquired together with the available Government waste lands gave sufficient acreage for the resettlement of dispossessed people. Various other arrangements were also made to facilitate the quick change over to new lands and to remove indebtedness of ryots. In regard to the construction of buildings in the new villages a cooperative arrangement between the Government and the people was made according to which land for the building sites was given free, roads, drains, wells, schools and temples were provided at Government cost, and the Government also contributed towards the construction cost of the houses, an equivalent of the value of the property which was submerged and could not be removed. The Engineering and Architects Department of the Government of Mysore gave every assistance in the design, layout and construction of these buildings. In this way the hardships of the dispossessed people, if any, were reduced to the minimum. This is a precedent which is recommended for application in the case of the dispossessed people from the Hirakud reservoir area.

PROGRAMME.

The programme of construction of the dam will be so arranged that the actual submergence of areas is gradual and spread over a period of about 5 years. Few areas are likely to be affected in the first two years. In this interval new areas set apart for resettlement should be made fit for occupation and a beginning made with the setting up of model villages. It will be very desirable to give an overlap of about six months in which the new settlers, while retaining their original lands, may shift their belongings, build houses and otherwise get their new lands into shape for occupation.

MODEL VILLAGES.

New village sites should be located after careful consideration of the various factors that go to make community life happy and full. Government should undertake to build at public expense places of worship, schools, community centres, roads, drains, etc., and otherwise plan the villages on modern lines and reserve areas for play grounds, agricultural farms and industrial development. The area reserved for building sites should be cut up into plots. Assuming that a particular village is to accommodate 500 families, sufficient space should be reserved after allotment of the necessary number of plots to these 500 families, to accommodate a further lot of 1,000 to 1,500 families. The remaining plots so reserved can subsequently be sold at a much higher price when land values go up as a result of the general prosperity brought about by the project. In this way large revenues will accrue to the Government which will more than repay the initial expenditure incurred by the Government in the layout of a modern village and the construction of public places. No credit has, however, been taken in the project for this additional income.

The new settlers should be encouraged by loans and grants-in-aid to build better homes than the ones they leave behind to be submerged in the reservoir area. In addition Government should provide free technical advice in the planning and construction of these homes.

CHAPTER VIII.

ALLOCATION OF COST BETWEEN FLOOD CONTROL, IRRIGATION AND POWER.**GENERAL POLICY.**

All structures built exclusively for irrigation e.g. headworks, canals, branches, bridges, etc., will be a direct charge to irrigation. All structures constructed exclusively for power generation e.g. power house, power channel, tailrace, turbines, generators, transformers, switch gear etc., will be a direct charge to power generation. All structures constructed exclusively for navigation e.g. navigation locks, lock channels etc. will be a direct charge to navigation.

The cost of the dam and control works should normally be distributed between all purposes, namely, flood control, irrigation, power and navigation. As the possibilities of navigation will be limited until such time as the lower dams at Tikarpara and Naraj are constructed, it is proposed, for purpose of the present estimates, not to charge any part of the cost of the dam to navigation. If and when the lower dams are constructed this question can be reopened. But the cost of structures exclusively constructed for navigation will be a charge to navigation.

The simplest method of distributing the cost of the dam between flood control, irrigation and power would be to do so in the proportion of the total stored water used for each purpose on the assumption that the dam is to be constructed exclusively for that purpose. For purposes of determining the stored water requirements, the worst conditions must be taken in account in each case. Thus, for the purpose of flood control the year of maximum flood (viz. 1834) requiring the maximum flood storage should be considered and for irrigation and power the year of minimum dry weather flow (viz. 1941-42) requiring the maximum withdrawal from storage should be taken.

STORAGE CAPACITY REQUIRED FOR FLOOD CONTROL.

As explained under 'Flood Moderation' in Chapter IX the amount of flood reserve at the Hirakud dam required to give adequate protection in the delta against floods of 1834 and 1872 is 3.51 m.a.ft. To maintain this flood reserve unimpaired, say for a century, it will also be necessary to make adequate provision for silt reserve. This reserve has been worked out as 1.2 m.a.ft. in Chapter V.

If the Hirakud Dam is to be constructed for flood protection only the gross storage capacity required will be $3.51 + 1.20 = 4.71$ m.a.ft.

STORAGE CAPACITY REQUIRED FOR IRRIGATION.

The statement below gives the quantities of water that will be drawn for irrigation during each month of the worst year from natural flow of the river and from storage after making due allowance for evaporation losses and the water requirements of irrigation lower down in the delta. The water requirements in the delta have been assumed on the basis of a continuous flow of 2,000 cusecs throughout the dry months. The figures in cols. 2, 3 and 6 have been taken from the annexure to Appendix VI.

Month.	Inflow during the month m.a. ft.	Evapo-ration losses m.a. ft.	Quantity required for irrigation lower down in the delta m a. ft.	Balance avail-able in the re-servoir m.a. ft.	Requirements for Irrigation.		
					Total m a. ft.	From flow m a. ft.	From storage m.a. ft.
1	2	3	4	5	6	7	8
November ..	0.51	0.04	0.12	0.35	0.37	0.35	0.02
December ..	0.38	0.03	0.12	0.23	0.15	0.15	..
January ..	0.29	0.04	0.12	0.13	0.15	0.13	0.02
February ..	0.13	0.03	0.12	—0.02	0.13	..	0.15
March ..	0.14	0.05	0.12	—0.03	0.15	..	0.18
April ..	0.11	0.05	0.12	—0.06	0.10	..	0.16
May ..	0.07	0.07	0.12	—0.12	0.10	..	0.22
June ..	0.07	0.05	0.12	—0.10	0.15	..	0.25
Total ..	1.70	0.36	0.96	0.38	1.30	..	1.00

The quantity of water required for irrigation from storage during the dry months in the worst year will, thus, be 1.00 m.a.ft. To this must be added the reservoir losses during those dry months viz., 0.36 m.a.ft. and also the silt reserve of 1.20 m.a.ft. the latter being necessary to maintain the useable storage unimpaired for a period of say 100 years and to raise the water level in the river to the extent necessary to feed the gravity channels. The total reservoir capacity for purposes of irrigation will thus be $1.00 + 0.36 + 1.20 = 2.56$ m.a.ft.

STORAGE CAPACITY REQUIRED FOR POWER.

Month.	Inflow during the month m.a. ft.	Evapo-ration losses m.a. ft.	Quantity required for irrigation lower down in the delta m.a. ft.	Balance avail-able in the re-servoir m.a. ft.	Requirements for Power.		
					Total m.a. ft.	From flow m.a. ft.	From storage m.a. ft.
1	2	3	4	5	6	7	8
November ..	0.51	0.04	0.12	0.35	0.64	0.35	0.29
December ..	0.38	0.03	0.12	0.23	0.46	0.23	0.23
January ..	0.29	0.04	0.12	0.13	0.47	0.13	0.34
February ..	0.13	0.03	0.12	—0.02	0.44	..	0.46
March ..	0.14	0.05	0.12	—0.03	0.50	..	0.53
April ..	0.11	0.05	0.12	—0.06	0.46	..	0.52
May ..	0.07	0.07	0.12	—0.12	0.48	..	0.60
June ..	0.07	0.05	0.12	—0.10	0.55	..	0.65
Total ..	1.70	0.36	0.96	..	4.00	..	3.62

The quantity of water utilised for power during the dry months in the worst year will thus be 3.62 m.a.ft. if only 68,000 k.w. are generated for pumping and 70,000 k.w. (or 116,666 k.w. at 60 per cent load factor) for other needs. With the reservoir loss of 0.36 m.a.ft. and silt reserve of 1.20 m.a.ft. the total water required for power will be $3.62 + 0.36 + 1.20 = 5.18$ m.a.ft.

From statement B of Appendix VI it will be seen that in 19 years out of 20, the water level in the reservoir will be higher than 580.00 (the dead storage level) even after drawing the required quantity of water for developing 68,000 k.w. for pumping and 100,000 k.w. (166,666 k.w. at 60 per cent. factor) of power for other needs. It is, however, proposed to ultimately utilise each

year all water in the reservoir down to R.L. 580.00. This will give an additional 30,000 k.w at 100 per cent. or 50,000 k.w. at 60 per cent. load factor. This latter will be firmed up with steam generation. The additional mean quantity of water thus used annually will be 1.20 m.a.ft.

With the reservoir loss of 0.36 m.a.ft. and the silt reserve of 1.20 m.a.ft. the total water used for power in this case will be $3.62 + 0.36 + 1.20 + 1.20 = 6.38$ m.a.ft.

SUMMARY OF RESERVOIR CAPACITY REQUIREMENTS.

The overall requirements of storage capacity (including dead storage, and in case of irrigation and power also reservoir losses etc.) for the different purposes of the project, assuming that the dam is constructed for that one purpose only, will be :

(a) If the reservoir is not to be depleted to 580 every year

Flood control ..	..	..	..	..	4.71 m.a. ft.	37.83%
Irrigation ..	..	..	..	..	2.56 m.a. ft.	20.56%
Power ..	..	..	..	..	5.18 m.a. ft.	41.61%
<hr/>						
12.45 m.a. ft.						100.00%

(b) When the reservoir is to be depleted to 580 every year.

Flood control ..	..	..	..	..	4.71 m.a. ft.	34.50%
Irrigation ..	..	..	..	..	2.56 m.a. ft.	18.76%
Power ..	..	..	..	..	6.38 m.a. ft.	46.74%
<hr/>						
13.65 m.a. ft.						100.00%

ALLOCATION OF COST OF DAM.

The full benefit of flood control will be realised as soon as the dam is completed. The benefits in respect of irrigation and power will accrue by stages and may take 10 to 20 years for full realisation. This would indicate acceptance of the basis (a) for allocation of costs between different purposes. On this basis the cost of the dam of Rs. 16.16 crores will be distributable as follows :

Flood control ..	..	..	..	..	37.83% of 16.16	= 6.11 crores.
Irrigation ..	..	..	..	..	20.56% of 16.16	= 3.32 crores.
Power ..	..	..	..	..	41.61% of 16.16	= 6.73 crores.
<hr/>						
100.00%						16.16 crores.

The unremunerative part of the cost of the dam allocated to flood control would thus be Rs. 6.11 crores.

DISTRIBUTION OF COST OF THE PROJECT.

The abstract of cost of the Project is given in Appendix XIV and is as follows:

(1) Dam and appurtenant works	16.16 crores.
(2) Main Canal, Branches distributaries and water courses	7.80 crores.
(3) Hydro electric installation	22.85 crores.
(4) Navigation	1.00 crores.
	<hr/>
	47.81 crores.

As the cost under items (2), (3) and (4) of the estimate will be a direct charge to the respective items of development, the final allocation of costs will work out as follows :

Flood control	6.11	6.11 crores.
Irrigation	3.32 + 7.80	11.12 crores.
Power	6.73 + 22.85	29.58 crores.
Navigation	1.00	1.00 crores.
	<hr/>	
	16.16 + 31.65	47.81 crores.
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CHAPTER IX.
FLOOD REGULATION
FLOOD PROBLEM.

Floods and drought constitute the two major problems of Orissa. The famine of 1865—1866, when food crops failed and nearly one million people died in the district of Cuttack alone and nearly 40 per cent of the population of the district of Puri perished, was followed by the flood of 1866; crops and property were destroyed, and what the drought had spared was engulfed in the wide flood waters. A much higher flood is reported to have occurred in the year 1834. High floods also occurred in 1855, 1872, 1933 and 1937. The estimated cost of damage by floods in 1937 was nearly 30 lakhs and in 1933, 56 lakhs. For the period of 29 years from 1910 to 1938 the total direct flood damage is reported to be 349 lakhs giving an average annual loss of 12 lakhs from flood damage. In addition there must be considerably more damage both direct and indirect which could not be determined.

The delta area of Orissa is traversed by five large rivers. Of these, the Swarnarekha and Burbalong at the northern end have their own problems. The main flood problem of the delta may be regarded as confined to the three major rivers, the Mahanadi, the Baitarani and the Brahmani. Of these, the floods in the Mahanadi are the most important, and their control must be the first concern of any scheme of flood regulation.

High floods in the Mahanadi.

The maximum floods on record at Naraj with their peak gauges and discharges are as follows :

Year of flood ..	..	1831	1855	1866	1872	1933
Month ..	..	Sept (?) Dusserah	July	July	?	August
Peak gauge ..	..	93.60 (?)	93.36	?	92.10	91.45
Peak discharge ..	..	1,571,000	1,543,431	?	1,503,367	1,412,000

Safe flood gauge at Naraj.

The following passage from the Preliminary Report of the Orissa Flood Advisory Committee 1938—Appendix II, gives an idea of the safe flood gauge at Naraj and states the flood problems of the delta.

“ Bellevue gauge on the Katjuri at Cuttack town is the warning gauge for Puri district. * * * * The maximum gauge reading was 27.80 in 1892 and the 1937 flood was 27.25. The amount of flood passing with 24.0 gauge I should consider as the safe limit beyond which it would be desirable to restrict floods, if possible. From a study of the past record of damage, it would appear that some slight damage is to be expected after the gauge reaches 23.00 and bad damage when over 25.00. With a gauge of 24.5 as happened on 27th July 1937, water passed over the countryside filling up all low lands and interfering with communications but causing no damage to houses. A prolonged flood at this height will of course cause damage to crops in low lying areas and affect houses ”.

“ **FLOOD VOLUME TO BE CONTROLLED** : With Bellevue gauge at 24.00 Naraj gauge above weir on a rising flood has an average

reading of 89.0 and according to Rhind's discharge table for this site the discharge would be about 1,140,975 cusecs. The 1855 and 1834 floods which Naraj gauge 93.36 and possibly 93.60 (unknown) are the highest floods on record, but are too extraordinary to be designed for. * * * Considering the highest floods from 1872(92.10), 1892 and 1896(92.10), 1920(91.88), 1933(91.45) and 1937 (91.50) we may take 92.10 as, being the maximum, not likely to be exceeded. * * *

In the present project, the maximum gauge for purpose of flood moderation has been taken as 93.60 with a peak discharge of 1,571,000 Cusecs.

Flood control investigations of 1862.

"In 1862 a survey party was sent up the Mahanadi to study the river system with a view to constructing flood reservoirs and to investigate the possibilities of making the Mahanadi navigable throughout the year by reservoir discharges and canals where necessary. This investigation went on for two years during which the Mahanadi catchment as far west as Bilaspur was studied for locating reservoirs. The report on this was considered by the Chief Engineer, but the navigation canal project was impracticable and, with the reservoirs being kept empty until nearly the end of the flood season, it was considered that no regular supply for extending irrigation in the delta could be given and it was not worth the expenditure for flood control alone, so the scheme was dropped and has not since been taken up."

BASIS FOR PRESENT PROPOSALS.

The safe gauge according to the above quotation will be 24.0 at Bellevue corresponding to 89.0 at Naraj (89.2 according to the Printed Floods Warning Chart of Orissa). The limiting gauge above which more or less bad damage may be expected will be 25.0 at Bellevue corresponding to 90.10 at Naraj.

The "Dusselira" flood of 1834 has been accepted as the absolute maximum. This occurred, possibly, in September with peak Naraj gauge at 93.60 and a peak discharge of 1,571,000 cusecs. In the absence of information about the floods of 1866 the next highest flood may be taken to have occurred on the 29th July 1855 with a peak Naraj gauge at 93.36 and a peak discharge of 1,543,431 cusecs.

If the delta area is to be saved from serious damage, the high floods must be so regulated by means of storage dam or dams that the flood level at Naraj shall not rise above 90.10 gauge (Bellevue 25.0) corresponding to a discharge of 1,226,000 cusecs. It will however, be desirable, if possible, to regulate the flood flows in such a way that the flood level at Naraj does not rise above 89.0 (Bellevue 24.0) corresponding to a discharge of 1,140,975 cusecs.

FLOOD CONTROL IN THE BASIN-WIDE PLAN.

The unified basin-wide plan for the Mahanadi Valley Development envisages the construction of three dams at Hirakud, Tikarpara and Naraj. The proposed storage at these three dams will be much in excess of what is required for absolute flood control of the Mahanadi. But the implementation of the basin-wide plan might take a very considerable period of time, and the protection of the delta area from floods is a matter of immediate importance. The possibility of affording adequate flood protection from the Hirakud reservoir has, therefore, to be given special consideration.

HIRAKUD RESERVOIR, AND FLOOD MODERATION.

A statement of high floods since 1868, the highest that occurred each year during each of the three monsoon months July, August and September, is given in Appendix VII, Statement II. These have been plotted on Plate XI. The highest recorded floods of 1855 and 1834 have also been similarly plotted.

The five highest floods of 1834, 1872, 1933, 1937 and 1939 have been analysed. The results of analysis are given in Statement I, Appendix VII and plotted on Plate XI. A time lag of 2 days (actually 40 hours according to Professor P. C. Mahalanobis "Rainstorms and River Floods in Orissa"—1932) has been allowed for the flood flows from Sambalpur to reach Naraj. Further, each flood has been assumed to stay at the peak level for 24 hours—an assumption which is on the conservative side. No record of daily gauges of the 1872 or 1834 floods exists. Their hydrographs had, therefore, to be constructed by a geometrical extension of the 1933 flood, the highest flood for which gauge record exists.

These analyses indicate that in the case of the 1933 and 1939 floods, the flood reserve of 2.79 m.a.ft. from R.L. 600 to 625.5 will suffice to keep the flood level at Naraj at or below gauge 89.0. In the 1872 flood, the pond at Hirakud will have to be temporarily raised to R.L. 630.5 and kept above R.L. 625 for five days in order that the flood gauge at Naraj may not exceed 90.0 (90.1 being the limiting gauge). By this the flood will remain above 89.0 for a period of five days only. The flood reserve in this case will be from 600.0 to 630.5 or 3.51 m.a.ft. In the 1834 floods, with a pond level at Hirakud kept above 625 for six days and rising to a maximum level of 630 the flood gauge at Naraj will not exceed 90.0. The flood reserve in this case will be from 600 to 630 or 3.42 m.a.ft.

The construction of the Hirakud dam will thus keep the flood level at Naraj below the absolute safe limit of 89.00 in the years of normal highest floods and below the limiting gauge of 90.00 in the years of abnormal highest flood, so that there will be no material damage due to floods in future. A liberal free board will be allowed at the dam as a safeguard against extraordinary floods.

FLOOD RELIEF TO SAMBALPUR.

With a flood reserve of R.L. 600.0 to 630.5 (3.51 m.a.ft.) the regulated releases from the Hirakud Dam will not exceed 700,000 cusecs for the 1834 flood, 611,000 for 1872 flood and 600,000 for the other floods. This will result in a lowering of the maximum flood levels at Sambalpur by 4.8 ft., 5.9 ft. and 6 ft. respectively and will thus afford considerable relief to Sambalpur town.

FLOOD PROTECTION AND COST.

With the height of the dam, the reservoir level, and the flood reserve mentioned above, coupled with a proper system of rainfall and flood warning, the Hirakud Dam alone may solve to a large extent the flood problem of the delta, in so far as this arises from the Mahanadi floods. The flood control effected by the construction of the Hirakud Dam will benefit the Delta areas in two ways—firstly, it will save damage to lands and property which on a rough valuation has been reckoned at Rs. 12 lakhs per year; secondly, it will make lands fit for irrigation and cultivation which at present cannot be so used because of the periodic flooding. It will also provide substantial relief to Sambalpur town by materially lowering the peak flood.

The capital cost of affording protection to the delta from destructive floods has been worked out in Chapter VIII and comes to Rs. 6.11 crores.

CHAPTER X. IRRIGATION.

NECESSITY FOR IRRIGATION.

At present Sambalpur District depends only on rain for crop production, and the failure of rain results in the corresponding failure of crops. From the 'normal' rainfall statement given in Appendix III it will be seen that in the Mahanadi catchment above Sambalpur, about 87 per cent. of rain falls during the four monsoon months and the balance of 13 per cent. is distributed over the remaining eight months of the year. The mean monsoon rainfall over the area proposed to be irrigated from the Hirakud reservoir is 47.49" against 43.15" over the delta. In the autumn months October and November, the rainfall is 2.78" and 8.37" respectively. In the succeeding months December to May, the corresponding figures are 4.55" and 8.15" respectively. The distribution of rainfall over the Delta is therefore much more favourable than that over the area proposed to be irrigated from Hirakud. This emphasises the need for irrigation in the latter area more so than in the delta.

EXTENT OF IRRIGATION.

The gross commanded area under the project is about 1,313,000 acres. The irrigable area is taken as two thirds of the gross area, and the distribution of crops in Kharif and Rabi is assumed to be as follows:

Kharif.

Paddy	..	..	70% of irrigable area	..	..	..	612,800 acres.
Sugar cane	..	..	10%	..	..	..	87,470 acres.
Cotton	..	..	5%	..	..	..	43,735 acres.
Other crops	..	..	15%	..	..	..	131,205 acres.

Rabi.

Wheat	..	..	25% of Kharif paddy	..	..	..	153,050 acres.
Other rabi crops	..	..	17½% of Kharif other crops	..	..	..	22,958 acres.
Cotton	..	..	Same as Kharif cotton	..	..	..	43,735 acres.

1,094,953 acres.

Out of this area, 619,035 acres will be served by gravity flow canals and 475,918 acres by lift canals. Twenty-five per cent. of the irrigated area has been assumed to bear double crop.

The gross commanded area, the irrigable area and the maximum discharge of each canal are given in the following statement :—

Name of canal.							Gross commanded area. Acres.	Irrigable area. Acres.	Discharge. Cusecs.
Left side lift canal	..	..	..	..	..	..	110,000	73,300	737
Left side flow canal	..	..	..	..	..	..	192,000	128,000	1,287
Irrigation canal from power channel	..	..	..	..	..	..	250,000	166,710	1,7676
Right side flow canal	..	..	..	..	..	..	300,000	200,000	2,013
Right side lift canal	..	..	..	..	..	..	436,000	290,500	2,920
Foreshore canal	..	..	..	..	..	..	25,000	16,700	167
Total							1,313,000	8,75,210	8,800

A net-work of distributaries will take off from these canals and all the cultivable area below the dam site on both sides of the river right up to the hills will be supplied with means of irrigation.

IRRIGATION IN THE DELTA.

Besides the 1,094,953 acres of land in Sambalpur District and Sonepur State which will receive irrigation from the Hirakud dam, the regulated supplies from the latter (ranging between 8,800 to 14,000 cusecs during the dry months against the present minimum of about 1,000 cusecs at Naraj) will provide protective irrigation to existing irrigated areas in the delta during critical periods of short supply and enable perennial irrigation to be extended to additional large areas in the delta, which cannot be brought under irrigation at present due to the likelihood of their getting submerged during floods but which will become available for irrigation as a result of the flood protection which will be afforded by the construction of the Hirakud dam. This additional irrigation may cover several lakhs of acres. The existing irrigation for the period 1935-36 to 1938-39 was 200,427 acres per year.

The navigability of the river made possible by the increase in minimum discharge of the river from 1,000 cusecs to over 8,800 cusecs will not be materially affected by the abstractions for the above extension of irrigation.

No credit has been taken in the project for the improvement and extension of irrigation in the delta likely to be brought about by the construction of the Hirakud dam, as it has not so far been possible to adequately investigate the irrigation situation in that area.

A thorough enquiry into the existing irrigation in the delta, the reasons for its being non-productive and the possibilities of improvement and extension seems to be urgently called for.

DUTIES.

Based on the duties in Madras, Hyderabad and other places where similar conditions prevail the duties adopted for different crops are as follows:

Crop.	Month.										Duties.
Paddy	July	..	..	..	..	..	160
					August	..	..	..	..	..	150
					September	..	..	..	..	..	100
					October	..	..	..	..	..	100
					November	..	..	..	..	..	120
Sugar Cane	January to May		..	..	..	..	60
					June	..	..	..	..	..	65
					July to December		..	..	..	..	120
Cotton	June to December		..	..	..	..	300
					December to June		..	..	..	..	200
Wheat	December to March		..	..	..	..	200
Other crops	June to December		..	..	..	..	200
					January to April		..	..	..	..	200

The same duties are adopted for both flow and lift irrigation.

WATER REQUIREMENTS.

The water requirements of different crops in the different months under the several channels have been worked out on the above basis and are given in Statements 3 to 9 of Appendix VI. The total water requirement for irrigation thus obtained will be 3.63 m.a.ft.

REVENUE.

The main items which subscribe to the revenue on an irrigation project are:

- (i) Water rate.
- (ii) Water advantage rate.
- (iii) Increase in land revenue.
- (iv) Interest on sales of crown waste or jungle area, if any.
- (v) Rent for temporary leases of Government lands.

Water rates.

Water rate is a charge for the supply of canal water for irrigation. Details of water rates charged in some provinces and States in the Orissa Delta are given in Appendix VIII. These are mostly for irrigation from weir controlled supplies. Storage reservoirs cost much more than weirs and so the charges for water from storage should be higher than those from weir controlled canals. It was, therefore, proposed in this project to levy water rates 25 per cent. higher than those current in the Orissa delta.

The Deputy Commissioner, Sambalpur, who was consulted in the matter was, however, of the opinion that the rates proposed were high and may be beyond the capacity of the people to pay. He suggested the following rates:

								Rs.
Rice	..	..	..	..	..	..	..	2 0 0
Cotton	..	..	..	..	..	..	..	1 8 0
Tobacco	}	..	..	..	..	..	..	2 0 0
Ginger								
Wheat								
Vegetables	..	..	..	..	..	..	..	1 8 0
Chena	}	..	..	..	..	..	..	1 4 0
Oil seeds								
Pulses								
Sugar Cane	..	..	..	..	..	..	..	4 0 0

It will not be equitable to accept the above recommendations. Water rates for supplies from storage should obviously be more, and certainly not less, than those charged in the Orissa Delta. With the advent of irrigation in the Hirakud project area, the quality of lands as well as their yield per acre will improve considerably. The cultivator here can, therefore, afford to pay at least as much as the cultivator in the delta.

For purposes of this project, the same rates have been provisionally assumed as those which are at present being charged in the delta except that in

the case of cotton Rs. 3|- per acre is proposed against Rs. 1|8|- in the delta. The proposed rates are given below :

Sugar cane	..	..	..	..	..	..	6	8	0	per acre.
Paddy ..	..	..	..	..	..	..	4	4	0	per acre.
Cotton ..	..	..	..	..	..	..	3	0	0	per acre.
Wheat ..	..	..	..	..	..	..	2	0	0	per acre.
Other crops	..	..	..	..	..	..	2	8	0	per acre.

Water advantage rate and increase in land revenue.

It is an accepted fact that with the advent of irrigation the quality of land as well as yield per acre will improve. The cultivator can therefore afford to pay to the Government a percentage of the additional earnings he makes in consequence. This charge can take the form of a betterment fee or increase in land revenue.

In Mysore for the irrigated area under the Krishnarajasagar Reservoir a betterment fee of Rs. 100|- per acre was charged. Similar charges have been levied in other storage projects.

The following extracts from "Rent settlement in Orissa" by P. T. Mansfield, Esq., dated 14th July 1933, shows the difference in the present rent assessment in Sambalpur and other parts of Orissa Province.

Page 9.... Sambalpur (1921-25).

"....But even after the settlement, the average rent in the district is only 6 annas 7 pies per acre."

Page 14.... Orissa (1922-32).

".....The average of the new rents amounts to about Rs. 2|±|- per acre in Balasore, Rs. 2|7|- in Puri Sadr and about Rs. 3|6|- in Cuttack."

The lands to be irrigated in the Sambalpur District will become as productive as, if not more so than, those in the Delta. The land revenue of such lands should therefore be brought in line with the rents charged in Puri and Cuttack Districts. At present the lands in Sambalpur District are classified under four categories, *viz.* 'At', 'Mal', 'Berna' and 'Bahl' lands and the corresponding rents are 2|3, -10|6, 1|-|6 and 1|6|6 per acre respectively. As irrigation will bring all classes of lands to a higher and more or less uniform standard of productivity, the revised rent should not be very different. With that object, it is proposed to increase the rent of lands by an average of Rs. 2|- per acre.

The Government of Orissa may consider these rates, decide on the actual increase for each class of land and incorporate these in the next settlement of the district which is already overdue.

Interest on sales of crown waste or jungle areas.

In other projects, interest on sales of Crown waste lands is credited to the project, the actual sale money being used for other purposes by Government. But in the Hirakud Project, most of the crown waste and jungle areas will be required for resettlement of the dispossessed people from the reservoir and no revenue by way of sales may be expected. There will, however, be some saving in the compensation figures for the lands submerged under the reservoir as these jungle areas can be given in exchange after being made fit for cultivation.

Lands for temporary leases.

The statement below shows the extent of marginal lands in the reservoir area which will become available each year for cultivation with the depletion of the reservoir and will remain so available till the reservoir again fills up.

Extent of submerged area available for cultivation on the Hirakud Reservoir for an average year.

Month	Reservoir level at the beginning of the month	Reservoir level at the end of the month	Area in acres.	Accumulated total area in acres	Date available from
1	2	3	4	5	6
October .. .	625	625	0	0	1st November
November . . .	625	623	4,400	4,400	1st December
December .. .	623	621	4,400	8,800	1st January
January . . .	621	619	4,400	13,200	1st February
February .. .	619	616	6,200	19,500	1st March
March .. .	616	611	10,500	30,000	1st April
April .. .	611	606	10,000	40,000	1st May
May .. .	606	599	14,000	54,000	1st June
June .. .	599	598	2,000	56,000	1st July
July .. .	598	605	—14,000	42,000*	1st August
August . . .	605	605	..	42,000*	1st September
September ..	605	625	—42,000	0	1st October

*Part of this area is likely to get submerged for a number of days for flood regulation.

The depletion of the reservoir would generally start about the end of November and continue till the 3rd or 4th week of June. Thereafter it is proposed to keep the reservoir always filled till end of September up to the bottom level for flood reserve, i.e., 605 in normal years and 600 in abnormal years. This flood reserve will be maintained throughout the season. From an examination of the flood moderation studies (Appendix VII. Statement I) it can be safely assumed that the reservoir will not rise above R.L. 615 more than once in twenty years and a level of R.L. 613 will not be exceeded in more than two years out of twenty. The area above the reservoir level of 615 will be 21,000 acres and above 613 will be 26,000 acres. It is therefore safe to assume that 20,000 acres of marginal lands will be available for cultivation from March to almost the end of September.

Rabi paddy is generally grown in Madras from about the middle of January to about the middle of April. About 10,000 acres of the marginal lands will become available about the middle of January and may be used for this purpose. An additional 10,000 to 20,000 acres of lands can be put under autumn paddy. For purposes of revenue forecast it has been assumed that 20,000 acres will be available each year from the marginal lands for growing one paddy crop. It is likely that in certain years this may go as high as 40,000 acres.

An annual lease rate of Rs. 4/- per acre is proposed for purposes of revenue forecast. The lease of these lands will, however, be auctioned each year, due consideration being given to the claims of people who originally owned these lands. These marginal lands with fresh rich silt deposits each year and with the water retained from the receding reservoir should grow extremely good crops.

Lift Irrigation.

There are large areas of high lying lands in the Sambalpur district, a good proportion of which are lying waste. In the interest of producing more food, these must be irrigated. The only way to serve these areas is by means of lift irrigation. Lift irrigation is bound to be expensive as it will involve not only the construction of the usual canal and distributary system, but also the cost of electrical power used in pumping, depreciation of pumping plant and the cost of their maintenance and operation. Assuming depreciation at 1.66 per cent. on the capital cost of Rs. 1 crore of the pumping plant and 1.5 per cent. as maintenance and operation charges, the annual cost on this account will be Rs. 16 lakhs. The cost of electrical power works out to Rs. 12 lakhs. Depreciation and maintenance charges along with the capital cost will form part of the common irrigation pool of capital cost, but the sum of Rs. 12 lakhs, the cost of electrical power, should, in equity, be borne by lift irrigation. This spread over 4.76 lakhs of acres would mean an average charge per acre of Rs. 2|8|-, which, it is felt, will be too heavy. It is proposed to charge an additional flat rate of Rs. 1|8| per acre over the entire area irrigated by lift. This implies that the lift irrigation will have to be subsidized in order to make the rate per acre within the capacity of the cultivator to pay. This subsidy is fully justified in view of the necessity for raising more food crops.

Moreover, the preliminary calculation of power required for lift irrigation at the largest pumping station is based on the assumption that the entire supply will be pumped into one channel at the maximum height of 150'. This requires about 50,000 k.w. based on ultimate development and the estimate of cost has been made on this basis. But on a more detailed examination, it may be possible to run three channels at different levels, lifting 50 ft., 100 ft. and 150 ft. and the quantity of water lifted to each level will be based on the area commanded by that channel. If the above is found to be feasible, total power required will be considerably less than 50,000 k.w. (approximately by 15,000 k.w.) and the cost of pumps correspondingly reduced. This will also reduce the cost of operation of pumps and therefore the annual expenditure on irrigation by approximately Rs. 3 lakhs.

The power thus saved can be utilised for general power purposes and sold at about Rs. 120 per k.w. against Rs. 20 per k.w. charged to irrigation and so the power side also will show a greater revenue without any increase in expenditure. The nett result is likely to be an increase of revenue of the order of Rs. 10 lakhs on the power side. The financial statements, therefore, are on the conservative side, and if the above materialises the subsidy to lift irrigation will be negligible.

REVENUE FORECAST.

Increase in land revenue.

The total irrigable area under the project will be 875,210 acres. As stated above it is proposed to increase the rent of all lands by an average of Rs. 2 per acre. The increase in land revenue on the above basis will be $875,210 \times 2 = \text{Rs. } 17,50,420$.

Water rates.

The areas irrigated by gravity flow and lift are given below:

Kind of crop								Gravity flow	Lift
Paddy Kharif	..	..	..	..	..	..	..	346,300	2,66,500
Sugar Cane	..	..	..	..	..	..	..	49,470	38,000
Cotton Kharif	..	..	..	..	..	..	..	24,735	19,000
Other Kharif crops	..	..	..	..	..	..	..	74,205	57,000
Wheat Rabi	..	..	..	..	..	..	..	86,600	66,450
Cotton Rabi	..	..	..	..	..	..	..	24,735	19,000
Other Rabi crops	..	..	..	..	..	..	..	12,990	9,968
Total								619,035	475,918
GRAND TOTAL								1,094,953	acres.

The revenue derived from water rate will be:

Kind of crop		Gravity flow					Lift					Total Rs.	
		Acreage	Rate Rs.			Amount Rs.	Acreage	Rate Rs.			Amount Rs.		
Paddy Kharif	346,300	4	4	0	14,71,775	266,500	5	12	0	15,32,375	30,04,150
Sugar Cane	49,470	6	8	0	3,21,555	38,000	8	0	0	3,04,000	6,25,555
Cotton Kharif	24,735	3	0	0	74,205	19,000	4	8	0	85,500	1,59,705
Other Crops	74,205	2	8	0	1,85,513	57,000	4	0	0	2,28,000	4,13,513
Wheat Rabi	86,600	2	0	0	1,73,200	66,450	3	8	0	2,32,575	4,05,775
Cotton Rabi	24,735	3	0	0	74,205	19,000	4	8	0	85,500	1,59,705
Other Rabi crops	12,990	2	8	0	32,475	91,968	4	0	0	39,872	72,347
			619,035				23,32,928	475,918				25,07,822	48,40,750

This gives an average water rate of Rs. 4/7/- per acre irrigated.

Irrigation Revenue.

								Rs.
<i>Indirect Revenue</i>								
From land revenue 875,210 acres at R. 2/- per acre								17,50,420
<i>Direct Revenue</i>								
From water rates								48,40,750
From lease of foreshore lands								80,000
Total								66,71,170 or 66·71 lakhs

Expenditure.

Interest at 11·12 crores at 3%	..	..	..	..	..	..	..	33,36,000
Maintenance and operation of canals 10,94,953 acres at 1·12 per acre	..	..	..	..	..	..	..	19,16,169
Depreciation of pumping plant 1,00,00,000 at 1·66 %	..	..	..	..	..	..	..	1,66,000
Maintenance and operation of the pumping plant 1,00,00,000 at 1·5%	..	..	..	..	..	..	..	1,50,000
Cost of electrical power for pumping 60,000 k.w. at Rs. 20 per k.w.	..	..	..	..	..	..	..	12,00,000
Total								67,68,169 or 67·68 lakhs.

CHAPTER XI.

POWER

The subject of power development at the Hirakud dam has been dealt with at length in Appendix IX by Mr. R. L. Narayanan, Chief Engineer, Electricity, Orissa.

WORKING TABLES

Detailed water studies have been made for 21 years from 1926 to 1946. Working tables have been prepared for each one of these years but only three such have been printed in Appendix VI. These are for the years 1932-33, 1938-39 and 1941-42, which represent a good, a normal and a very bad year, respectively. The salient points of the working tables for the entire period 1926-46 have been summarised in Appendix VI, statements 'A' and 'B'.

INSTALLED CAPACITY.

Fifty million acre feet of water annually flow down the river at this site. This implies a tremendous power potential. But the development of the potential will be limited by the physical features of the dam site, economic considerations, and more particularly by a consideration of the extent of areas to be submerged in the reservoir and the difficulties of resettlement of the dispossessed people.

After due consideration of the above and other factors, e.g., flood control, irrigation and financial aspect, it is proposed to install a capacity of 350,000 k.w. at Hirakud to carry a peak load of 300,000 k.w. This power can be generated in all years except occasional dry ones. In the latter case the deficit to a maximum extent of 50,000 k.w. at 60 per cent load factor (installed 75,000 k.w.) is proposed to be made up from steam generation. The hydro-power generated in that case will be 1524 million units and the supplemental steam electric 87.6 million units, during the year, the latter being 5.4 per cent. of the total generation.

Provision has been made in the design of civil works and penstocks to enable the installed capacity to be raised subsequently to 475,000 k.w., if the demand for seasonal power develops or if the construction of a dam or dams higher up the Mahanadi or its tributaries makes available additional regulated supplies for the generation of further firm power at Hirakud.

The power generation will be done in two parts; one at the main dam at Hirakud to utilise the fall created by the construction of the dam; and the second at the subsidiary dam, forming the balancing reservoir at the end of the tail race from the upper power house, to utilise the steep slope in the river below Hirakud. The heads at the two power houses are about equal (operating heads 85 ft.). For a total installed capacity of 350,000 k.w. it is proposed to instal 6 units of 25,000 k.w. each at the upper power station and 8 units of 25,000 k.w. each at the lower power station. For the ultimate installed capacity of 475,000 k.w. there will be 8 units in the upper and 11 units in the lower power station.

The present financial forecasts deal with an ultimate installed capacity of 350,000 k.w. only.

PROGRAMME OF DEVELOPMENT

The installation of units will be done in stages to suit the development of load. Financial results have been worked out for 100,000, 150,000, 200,000, 250,000 and 350,000 k.w. installed. The most satisfactory installation appears to be one of 200,000 k.w. at the outset with Tata Iron & Steel Works at Jamshedpur connected. The latter will provide a good initial load and permit gradual development of other industrial loads to the mutual advantage of Orissa and Tata Works. But the project will fail in its purpose if it is merely constructed as a financially economic proposition or for the benefit of an existing undertaking. The main purpose of the Project is to better the lot of the common man and, with cheap power, to afford large scale opportunities for rural electrification and the development of industries in the project area. For this purpose industrial development must be planned and schemes for setting up industries implemented simultaneously with the construction of the Hirakud Dam Project. Side by side, urgent consideration must be given to rural electrification, and manufacture of fertilisers.

From a consideration of the construction programme and the manufacturers capacity to supply hydro-electric machinery it will be safe to assume that the first set of units can be installed and put into operation in four years from the date of start of construction of the Project.

FINANCIAL RESULTS.

According to the provisional power rates given in the statement at the end of Appendix IX, the average rate per k.w. of peak demand per year will gradually drop from Rs. 160 to Rs. 100 with the progressive rise in load. For pumping load, the rate per k.w. year of peak demand will be kept uniformly at Rs. 20. This involves an element of subsidy, which is justified in the interest of raising more food crops.

The detailed rate structure for the various types of loads has not been dealt with in this report, but it will follow the generally accepted principles. The rates will depend on the size of the load, the load factor, the distance of transmission and the nature of the industry concerned. For different industries consideration will have to be given to the capacity of the industry to pay, its importance in the general economy of the country and the cost of alternative sources of power, if any. For instance, the rate of power for chemical industry and aluminium industry will be kept low and may be nearly equal to the over-all cost of generation.

In comparing the proposed rates for power in this project with the rate structure of existing hydro-electric or steam electric stations in India, the increase in the present day cost of hydro electric machinery, civil works and installation over the pre-war costs should be kept in mind. The present day costs are well above 200 per cent. over the pre-war costs.

With the proposed first stage of development of 200,000 k.w. linked up with the Tata steam station, it will be possible to sell power for lift irrigation at 0.086 anna per unit and for industrial and other purposes at 0.430 anna at the consumer's end, with an annual expenditure on power of 123.08 lakhs and revenue return of 185 lakhs of rupees. At the ultimate development of 350,000 k.w. the power rate for lift irrigation will remain the same, but that for industrial and other purposes will be reduced to 0.358 anna per unit. The total annual expenditure will in that case be 168.57 lakhs and annual return 252 lakhs giving a net annual saving of ₹3.43 lakhs (see Appendix IX).

SAVING IN COAL.

Assuming a coal consumption of 2 lbs. per unit generated the generation per year of 1,524 million units of hydro-power will save to India 3,048 million lbs. or $1\frac{1}{2}$ million short tons of coal each year which would otherwise have to be used to generate that much power from steam electric plant. This will be an important step towards conservation of our limited resources in coal.

LINK UP WITH OTHER STATIONS

The Hirakud power stations will be connected to the steam electric stations at Jamshedpur and Nagpur in the early stages and will be eventually linked up with the proposed Tikarpara, Naraj and other hydro-power stations of the Mahanadi basin with a power potential of over three million k.w., the hydro-power station at the Kosi dam (423 miles) designed to generate 1.8 million k.w., the Tista hydro station (440 miles) designed to generate about 400,000 k.w., the Damodar Valley hydro and steam stations (between 200 and 250 miles) designed to generate about 300,000 k.w., the Rihand hydro station in the Sone Valley (211 miles) designed to generate about 200,000 k.w., the Machkund hydro station (under construction 224 miles) designed to generate 100,000 k.w., the Ramapadasagar hydro station (372 miles) designed to generate 75,000 k.w. and the various other hydro and steam stations which may be installed within economic distance.

This will constitute a most important electric grid which will make for the rapid industrialisation and development of Orissa, Bengal, Bihar, C.P. and Berar, United Provinces, the Eastern States, Madras and other adjoining areas and will enable electricity to be carried to every village and every hamlet within range of this grid.

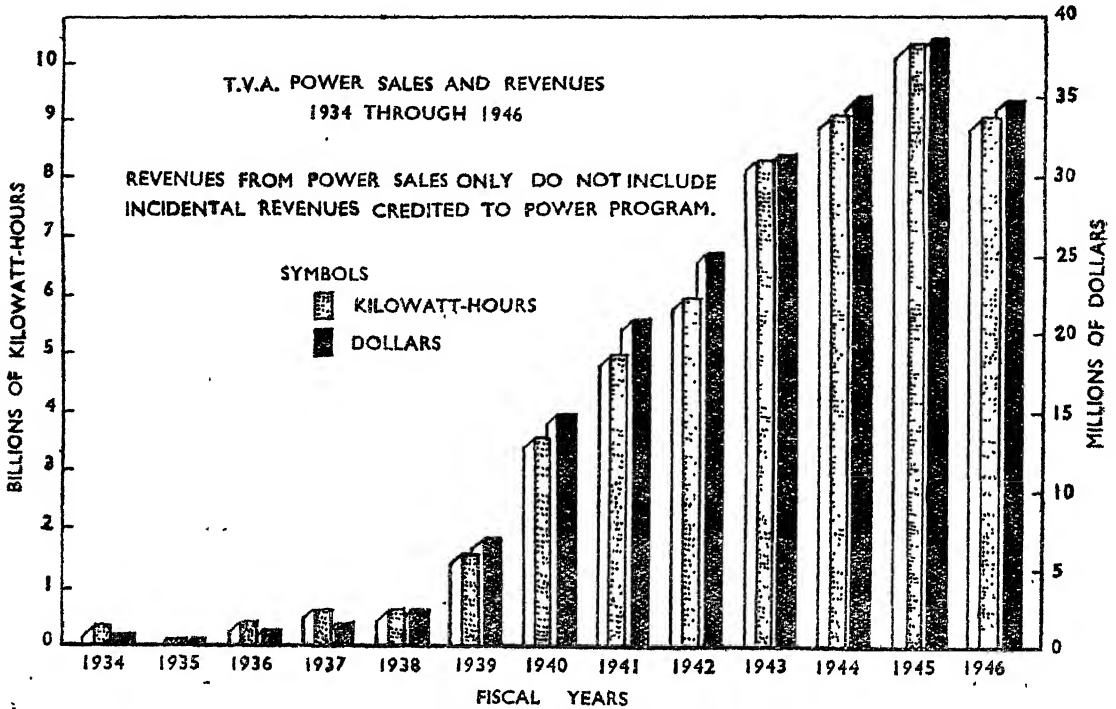
NEED FOR POWER

A question has been raised as to the necessity of generating this "enormous" amount of power at Hirakud where there is practically no demand at present, and particularly when the Orissa Government has recently sold the use of 20,000 k.w. out of its share of power at Machkund to Madras for a period of 99 years. It is argued that if Orissa could not use the 20,000 k.w. they have thus sold to Madras, she cannot be expected to utilise the 300,000 k.w. of power that are proposed to be generated at Hirakud. Machkund is situated at one end of the Province and away from the prospective market. Hirakud is situated in the heart of the prospective industrial belt of India (see Plate II), which has unlimited scope for development, if cheap power can be made available for the purpose. Aluminium, steel, ferro alloys, paper, cement and textiles—are among the manufactures that can be set up in the neighbourhood of Sambalpur. One single industry like aluminium, paper or steel can use up the entire output 300,000 k.w. at this station.

The T. V. A.

Similar doubts were expressed by the people of the Tennessee Valley before the new Tennessee Valley Act was passed. The total power generation in the region was about 30,000 k.w. in 1932. The people were poor, backward and apparently content with their low standard of living. They were opposed to any schemes of development. Then came the T.V.A. In the course of 10 to 12 years the power generation rose to nearly 2,000,000 k.w. the standard of

living went up, new industries came into being, agriculture was improved and vast volumes of traffic came to be handled through the newly created navigable waterways of the Tennessee river. The doubters of yesterday became the most ardent supporters of the new order brought in by the T.V.A. Of the 12,500 million units generated in 1946, 96 per cent. was hydro. The progress of power development on the T.V.A. is best illustrated by the following graph which has been reproduced from one of the T.V.A. bulletins.



The Russian parallel.

A most apt parallel is afforded by the Dnieper dam in U.S.S.R. the main features of which development are quoted from the December 1946 issue of the *Consulting Engineer* :

“ When the Dnieper dam was completed in March, 1932, it meant to the thousands of workers who had built it far more than the end of a job which had lasted more than four years. It meant that in spite of endless difficulties, of lack of modern equipment and practically no previous experience of hydro-technic work the Russians had succeeded in erecting the biggest and one of the most important dams in Europe. The moral significance of this fact was as important as the actual benefits which resulted from the erection of the dam.

“ During the nine brief years of its existence, the dam transformed the Backward, Agrarian Ukraine into a prosperous agricultural and industrial area producing coal mining, metallurgical, power and electrical equipment and steam locomotives and railway cars. In addition plants were built which produced soda, nitrates and super-phosphates.”

In 1941 this dam was blasted to make it useless to the approaching Germans. At the end of the war the work of the restoration of the Dnieper station with

an increased capacity was taken up with vigour, work being continued 24 hours a day.

“ To consider these prospects (opened by the restoration of the Dnieper dam) make a brief mental excursion over the Dnieper industrial area. North of the station is the City of Dnipropetrovsk (former Yakerino-sleav). Here are located large steel mills producing various grades of metal, including high grade alloys. A large automobile factory to manufacture trucks is now under construction in Dnipropetrovsk ”.

“ On the banks of the Dnieper is another city of metal—Dnieprodzerzhinsk. Before the war it had several blast furnaces working on ore from Krivoi Rog Basin which is located a short distance away. The Krivoi Rog Basin feeds the entire southern iron and steel industry, which before the war contributed two-thirds all the Soviet ferrous metals ”.

“ In old Russia the owners of iron ore mines attempted to organise production of metal in the immediate vicinity of the mines. Industrial development in Tsarist Russia, however, was hampered by a lack of equipment the general backwardness of the country and its dependence on foreign countries. Foreign industry exploited Russia as a mere source of raw materials for Western-European industry ”.

* * * * *

“... The three industrial centres—Dnipropetrovsk, Dnieprodzerzhinsk and Nikopol—developed rapidly after the Dnieper hydro-electric station was built. They received an abundance of cheap energy, the cheapest in the country. Inexpensive power also gave rise to the large iron and steel and machinery centre of Zaporozhye, situated in the immediate vicinity of the station.

“ Almost simultaneously with the building of the Dam, two iron and steel mills were erected. One, fitted with blast furnaces and open-hearth furnaces, had the biggest rolling mills in the country and produced primarily for the automobile industry. The other mills specialised in the production of alloy steels for automobile and aircraft motors.

“ A large aluminium plant was also built in Zaporozhye. Aluminium, as is well known, requires large quantities of power for its production. An average aluminium plant consumes 10 to 15 times more power than a large machinery plant. That is why aluminium plants are usually built next to large power stations.”

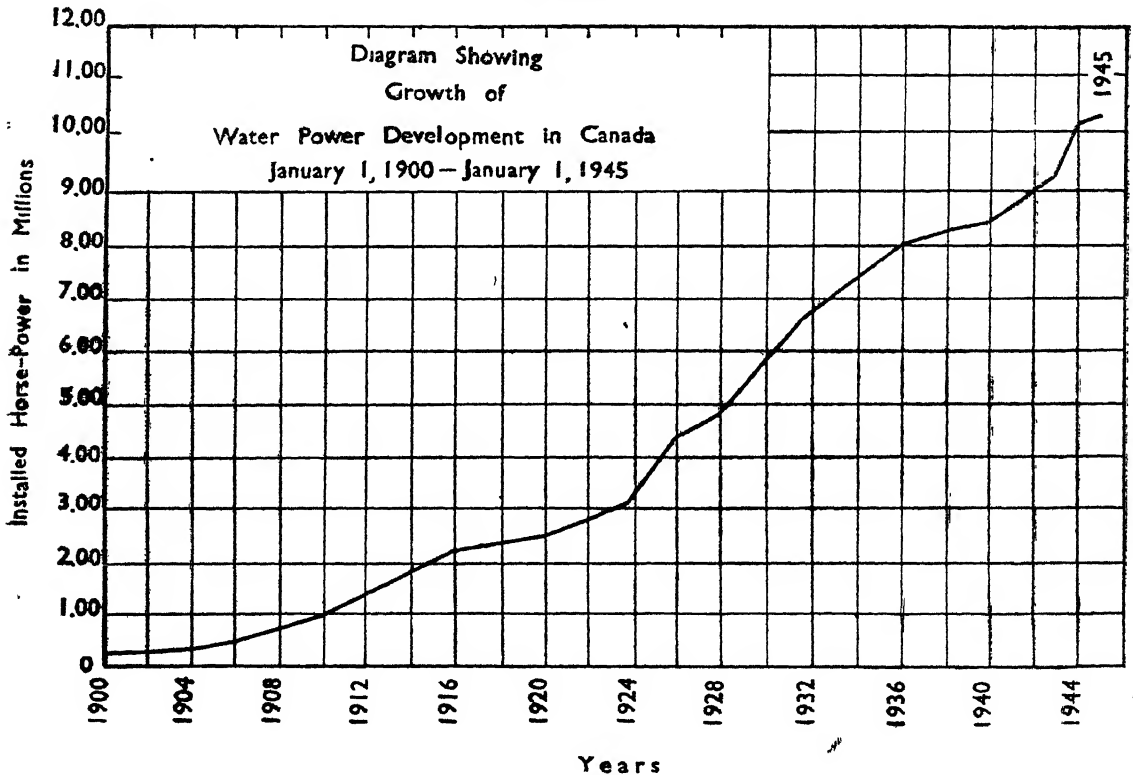
The Dnieper station had originally nine turbines of 90,000 h.p. each which would correspond to a total installed capacity of between 500,000 and 600,000 k.w.

The above quotations faithfully reproduce the present plight of the inhabitants of Sambalpur and Orissa, and further give a vivid picture of what Sambalpur and Orissa become, when the Hirakud project materialises. Within a short radius of Sambalpur there lies a good part of the mineral wealth of India (see Plate II)—iron, manganese, bauxite, copper, graphite, coal, mica, limestone, lead, asbestos, etc. Also there are large forests of bamboos, salwood and teak. There are extensive areas of grass for paper manufacture. And, there will be added annually 340,000 tons of paddy and other crops to the existing produce to give additional work to the factories and food to the people.

Canada.

Canada affords a good example of the transformation from agricultural economy and backwardness to industrialisation, unprecedented prosperity and power. Canada lacks coal but she has immense water wealth in her snow-fed perennial streams. She has vast forests, nickel and other mineral deposits. With cheap hydro-electric power she has become the biggest exporter of newsprint in the world. The per capita use of electricity in Canada is the highest in the world. Her population is about 12 million souls, but by virtue of the planned conservation and utilisation of her water resources she has risen to a position of great eminence among the industrial nations of the world. The total firm power potential of Canada is 25,439,400 h.p. In 1900 the total water power installed was 200,000 h.p.; in 1945 it was 10,283,763 h.p. of which nearly 3.3¼ million h.p. was for the manufacture of only paper. The following graph taken from the 1945 Annual Report of Canada illustrates the growth of power installation in that country.

(Graph).



Sweden.

Sweden is another example where the people have risen to great heights in industrialisation and standard of living. Quoting partly from the December 1946 issue of the *Consulting Engineer*, the tremendous development of Swedish industry under present conditions is due to the existence of vital raw materials and abundant hydro-electric power combined with long industrial tradition. The industrial resources of Sweden are remarkable in a country of 6½ million. Today Sweden produces no less than 2,000 k.w.h. per annum per inhabitant, a figure exceeded only by Norway and Canada and putting Sweden in the same category as the United States and Switzerland.

Out of a total power potential of about $5\frac{1}{2}$ million k.w. nearly $2\frac{1}{2}$ million k.w. have been developed so far.

Quoting from Sweden, Trade and Industry, 1945 "Swedish industry in general is almost entirely electrified, and this applies also to handicrafts and the home industries. All the main lines of the Swedish railways are electrically operated. The countryside and agriculture are provided with electric light and power to a very great extent, about 90 per cent. of the total population having access to electricity for all domestic purposes, to some extent even for heating and cooking. On these counts Sweden may probably be regarded as being more completely electrified than any other country especially considering how sparse the population is in many areas.

The country's lack of coal and mineral oil has naturally been a reason for providing industry with electric power to the fullest possible extent, especially when this could be accomplished on the basis of the country's own water power.

Most Swedish power plants of any size, state and private, are now connected up to form a grid system both for normal working and for rendering or receiving assistance in case of shortage of water in one district or another. The main transmission lines have now been extended so far that the system connects power consumers in the southern parts of Sweden and even Denmark with Swedish hydro-electric plants in Lapland a distance of 1,250 miles".

Orissa's opportunity.

If only cheap power can be made available there seems to be no limit to the opportunities for industrial development of Orissa and the neighbouring States with their population of nearly 12 millions, and with large deposits of key minerals within easy reach.

With the growth of industries, the demand for power will not be limited to 300,000 k.w. only but will rise to, perhaps, three million k.w. or more. Fortunately, the additional power will be available from the Tikarpara dam with its power potential of two and a half million k.w. and the Naraj dam with its power potential of nearly one million k.w. In this set up Sambalpur may well become the Pittsburgh of India and the Mahanadi Valley a great industrial belt with unlimited possibilities for service to the nation during peace and war.

The construction of the Hirakud dam is of importance not merely to the district of Sambalpur or to Orissa and the Eastern States, but also to India as a whole. It will give a most welcome lead to other parts of India where, as in the case of Orissa, the water wealth of the region, which is now being wasted to the sea, can be harnessed in the service of the common man and the nation. It will help Orissa and India to rise to the eminence that is of the United Kingdom, United States, Russia, Canada and Sweden today.

CHAPTER XII. NAVIGATION.

It is generally recognised that carriage by water is cheaper than any other form of transport. In the case of heavy goods or bulk cargoes water transport may compare favourably with that by railway in point of speed.

The great rivers of Orissa should afford a magnificent highway for the products of Central India, but during the rains they become dangerous for navigation due to the high floods they bring down, and during the rest of the year the current is sluggish and the volume of water small. Numerous sand-banks and jutting rocks obstruct the channels in the dry season and so only small boats can be navigated.

The river Mahanadi being the largest was formerly the main outlet for the trade of the interior as well as the Cuttack district. But since the opening of railway, river borne trade has greatly diminished. Boats are, however, still taken up to Sonepur and go as far as Arang in the Raipur District of Central Provinces.

In the delta area there were at one time regular daily services for passenger and trade operations between Cuttack and Kendrapara and Cuttack and Talgunga and bi-weekly services between Cuttack and Chandbali. The trade peak is said to have been reached before World War I. It is understood three companies were in competition operating five steamers weekly. Traffic by river has since been gradually on the decline. It was almost completely stopped in 1942-43 as a safety measure against the threatened Japanese landings. Subsequent to that river traffic has been negligible.

Navigation on the Mahanadi has a great future if the flow of the river can be regulated, the river channel cleared and conserved, and navigational aids such as lighted buoys and transits provided. The Mahanadi Valley and its adjoining areas are rich in mineral and forest wealth. With the construction of one or more dams, great development in the agricultural and industrial fields can be anticipated. The great waterway of the Mahanadi with proper conservancy arrangements would then open up great possibilities of inland water transport for the distribution of industrial and agricultural products of the area in the local markets as well as for their export by sea to other ports of India and abroad.

Deepsea port at Chandbali.

The present port of Chandbali provides two berths for steamers about 250 ft. in length. The deep water fore-shore extends approximately 2,000 ft. upstream from the Port Office. This distance is sufficient for six ships of 250 ft. The present capacity of the port is 800 tons per day with six ships of expansion to 2,400 tons per day based on 10 ft. draught. With dredging and navigational aids this capacity could possibly be increased by 40 per cent.

Dhamra port & potential capacity.

A site is available 16 miles downstream of Chandbali at Dhamra where there is about $1\frac{1}{2}$ miles of suitable river, all sheltered from the south by Kalibanj island, from the west and north by the main land, but open to easterly gale. This site appears to provide sufficient river to accommodate 10 ships of 300 ft. length anchored in the stream and 20 to 25 ships moored to the river bank. The capacity of such a port with modern mechanical equipment may be

taken as 800 to 1,000 tons per ship per day. From a navigational point of view the river could be maintained at 12 to 15 ft. at low water spring tides by dredging, should the development of the province justify the expenditure for a port of such dimensions. Thereby, ships of, 20 to 24 ft. draught would be afforded an uninterrupted passage by a channel only 6 miles from the sea.

The Mahanadi Valley development provides for the regulation of discharge of the river during dry season, giving a minimum of 8,800 cusecs after the construction of the Hirakud dam, 24,000 or 84,000 cusecs after the construction of the Tikarpara dam, and 33,000 or 93,000 cusecs by the addition of the Naraj dam, according as the Tikarpara dam is constructed to R.L. 350 or 430. Under existing conditions the minimum flow of the river may be less than 1,000 cusecs.

The extent to which such increase in the dry weather discharges of the river may affect the navigability of the river to the Port of Chandbali is being investigated. But it is reasonable to expect that a very deep river with unobstructed passage to the sea will result and will afford accommodation for ships as large as those trading in the other large ports in India. Under these conditions, it is estimated that the harbour area in the vicinity of Dhamra will permit the development of a port that should handle trade of the order of 5 to 6 MILLION TON PER ANNUM. The pre-war tonnage handled during 1939-40 in the Calcutta, Bombay, Karachi and Cochin Ports was 9.97, 5.33, 2.13 and .95 million tons respectively.

Need for additional ports.

There is great need for additional ports in India. There is no reason why the port of Chandbali (Dhamra) should not develop into one of the major ports of India as a result of the great industrial development consequent on the construction of the Mahanadi Valley Project. The following quotation from a recent report on the Port of Calcutta by Mr. A. Webster, CIE., MICE., will be of interest.

“The chief unpredictable item concerning the future of the Port, has reference to the constitutional changes which are now in progress and the enormous extent to which India's internal and external trade should expand in keeping with a rapid increase in the standards of living of her 400,000,000 inhabitants.

“It will be difficult to find an exact parallel with India's potential trade developments at this stage of her career, but the volume of a country's trade is generally reflex of her prosperity, and it should not be unreasonable to assume that a relatively small increase in the standards of living of India's vast population, would suffice to bring about trade development which may make past records appear puny by comparison.

“It should be easy to make out a *prima facie* case for a substantial increase in India's future sea-borne trade, by drawing comparison between this, and more highly developed and industrialised countries, like the United States of America and Great Britain.

“For example, the total volume of India's foreign and coastal sea-borne trade during 1939 was approximately equivalent to 0.05 ton per head of the population, whereas the corresponding figure for the U.S.A. was between 2 and 3 tons per head, and for the U.K. about 4 tons per head.

“The two largest ports in India, *viz.*, Calcutta and Bombay handled between them about 15½ million tons of goods in 1939, whereas London and Liverpool the two largest ports in the U.K. handled during the same year,

a total tonnage of over 63 millions. The total tonnage of goods handled in 1939 by all Indian major ports as well as those of Indian States amounted to 21½ millions, which was less than the total handled by Liverpool alone, during the same period.

“When it is remembered that the population of India is about 10 times that of the U. K. and the total of India’s sea-borne trade in goods is less than one half of that handled by London alone, it will be seen that even allowing for the fact that the U.K. has to import a large percentage of her foodstuffs, there is still great scope for the development of India’s ports generally.”

Inland ports on the Mahanadi

On full development of the Mahanadi Valley Project every state bordering the river may have its own port and ship direct to Cuttack, Calcutta or any other port to which trade may be established. Possible river ports are the following:—

Cuttack.	
Dasapur.	Left bank for Athgarh & Dhenkanal.
Sopurothpur.	Left bank for Baramba.
Kantilo.	Right bank for Khandpara.
Nuapatra.	Left bank for Narsingpur.
Sania.	Left bank for Daspalla.
Tikarpara.	Left bank for Angul.
Kaintragarh.	Left bank.
Baudh.	Right bank.
Baunsumi.	Right bank.
Sonepur.	Right bank.
Binka.	Right bank.
Sambalpur.	Left bank.

Birupa river route.

From preliminary investigation it appears that the increase in the dry weather flow of the Mahanadi as a result of the regulation of discharge made possible by the construction of one, two or three dams, will offer tremendous scope for developing an all-river route, *via*. the Birupa river to the sea. Adoption of this route would require the construction of one lock only in the weir at Jagatpura. This aspect is being further investigated.

Hirakud dam—Its effect on navigation.

The construction of the Hirakud dam alone will result in a reduction of the flood peak discharges at Sambalpur to between 600,000 and 700,000 cusecs, against a probable maximum of 1,100,000 cusecs, and in an increase in the low water discharge from less than 1,000 cusecs to a minimum of over 8,800 cusecs. Between Hirakud and Dalab, navigation will be *via*. the power-cum-navigation channel extending into the reservoir through a series of locks. Below Dalab there are 14 places in a distance of 84 miles to Dholpur, which would involve blasting operations to permit unrestricted movement of moderate sized crafts of capacity between 600 and 800 tons. Further down, some dredging will have to be done to keep the channel navigable to Cuttack. With the construction of

the Tikarpara and Naraj dams the necessity for dredging and blasting will mainly disappear depending, of course, on the reservoir level at Tikarpara.

With the construction of one dam at Hirakud, the river could be made navigable for large tows made up of several units of 600 to 800 tons capacity each, as far as Dholpur, 200 miles from Chandbali; and by blasting the remainder of the channel, these tows could proceed as single units for the remainder of the journey to Dalab, and thence through the power channel to the Hirakud pool.

With the construction of the three dams it should be possible to maintain a minimum depth of 9 to 10 ft. from the border of the Central Provinces to the deep sea port at Chandbali or Dhamra, and thus open unlimited possibilities of Inland Water transport linked with ocean going traffic. Depths of nearly 30 feet could possibly be maintained from the sea to Dhamra Port.

CHAPTER XIII.
MISCELLANEOUS.
FISH CULTURE.

The success of any reservoir from a fishery standpoint is linked with the amount of fluctuation in water level. The amount of this fluctuation determines the success or failure of the natural propagation of fish. It also determines whether or not certain species of aquatic plant necessary for, and helpful to, fish life can be established. Many desirable aquatic plants will grow only in relatively shallow water. If the annual change in water-level is more than this depth, and if it occurs during the growing season of such plants the likelihood of such plants becoming established is slight.

The question of fish culture at the Hirakud reservoir is being specially examined by a fisheries expert. Fish hatcheries will be constructed where the fish will be hatched for the purpose of stocking the reservoir. It is possible that a series of rearing pools may have to be located at strategic places in the reservoir where the fry can be retained till they reach a size sufficient to ensure their safety upon transplantation into the main reservoir.

MALARIA CONTROL.

Malaria is more or less prevalent throughout Orissa and the Eastern States. The building of an extensive reservoir or reservoirs in the region makes it necessary to deal adequately with the problem of controlling the breeding of the malaria bearing mosquito in and along the shores of the lakes. In the case of the Tennessee Valley the problem of malaria control became essentially a problem of reservoir control, and had to be co-ordinated with other operating requirements. The following is a quotation from one of the T. V. A. bulletins.

“In the case of the reservoirs on the main river, the desirable water-level regulation for malaria control is to fill the reservoir to the maximum elevation in the early spring, hold the water at this level for a short period, then drop it to the normal upper operating level. This tends to strand floating debris and to inhibit vegetable growth around the margin of the reservoir. Then, during the mosquito breeding season (which extends from about May 15 to October 1 in this region), the water levels are subject to cyclical fluctuations about a foot, at one week intervals combined with a gradual water-level recession. Water-level fluctuation is one of the most effective methods of combating the production of mosquitoes, as it strands the eggs and larvae and also draws them out from the protective vegetation, exposing them to their natural enemies. On the large storage reservoirs it is not feasible to fluctuate the water but the extensive draw down keeps the edge of the water away from vegetation and on a clean shore.”

“Supplemental means of mosquito control are also employed, including the application of larvicides by spraying from boats or dusting from airplanes. It has been found that thorough initial clearing, with re-shrubbing of a marginal strip just before impoundment, pays good dividends in reducing the annual cost of larvicidal treatment. In certain localities, it has proved economical to dike

and dewater large shallow areas. Again, flat, irregular shore areas have been treated by cut-and-fill excavation to produce a straight, steeply sloping shore."

It is proposed to adopt measures of a similar nature in the case of the Hirakud reservoir (and of other reservoirs if and when constructed). Stagnant pools, wherever existing, will be drained or dewatered by pumping. Drainage in general, will receive special attention.

A malaria expert has been appointed to go carefully into the entire problem of malaria and its control in the project area.

FORESTS & SOIL CONSERVATION.

The problem of forests and soil conservation will receive special consideration. A special forest officer has been appointed to go into the question of forests, their regulated cutting and afforestation with a view to bring the forests to maximum productivity and to conserve the forest wealth of the area for optimum exploitation. This officer will work in close co-operation with the local forest and agricultural officers. A brief abstract of the preliminary report of this officer is given in Appendix XI.

RECREATION

The lake formed by the Hirakud dam will afford great recreational facilities and will attract holiday-makers and tourists from all over India. The experience in other countries, notably the U.S.A., shows that these artificial lakes rapidly become centres of attraction. Large revenues accrue to the local people from tourist traffic. At Norris reservoir of the T.V.A. some idea of the popularity of boating may be obtained from the fact that two years after the completion of the dam, approximately 1,200 boats were in use. Along the shoreline of the lake extensive parks will spring up, with picnic grounds, cabins and other facilities, adding to the attraction of the place.

SEA-PLANE BASE.

The great expanse of the Hirakud reservoir even at its lowest level will afford a satisfactory landing for seaplanes. Because of its strategic location, this lake may develop into an important sea-plane base.

CHAPTER XIV

INDUSTRIAL POSSIBILITIES

GENERAL

The population of Orissa is mostly occupied in agriculture. The standard of living of the people is low mainly as a result of almost exclusive rural economy of the province. There are a number of cottage industries, but none on a large scale. Orissa and the adjoining states and provinces have many key raw materials, intelligent and industrious labour, tremendous power possibilities (over 4 million k.w. on the Mahanadi and possibly another million on the other rivers) and large waterways which can be made navigable. With cheap power and water transport, many large-scale industries can be set up at Sambalpur and elsewhere and their output carried cheaply to the markets of India and abroad over the great waterway of the Mahanadi, and then over the sea. With planned utilisation of its resources, Orissa can become a great centre of industry and the standard of living of the people very materially raised.

In Appendix XII Mr. M. L. Narasimha Aiyangar, Director of Industries, Orissa, has dealt with some of the industries that can be economically set up in Orissa and the provisional power requirements for the purpose. The possibilities of these and other industries are reviewed in this Chapter.

MINERAL AND FOREST RESOURCES

The index map (Plate II) indicates the chief mineral deposits in Orissa and the adjoining provinces and states. The quality and extent of some of these deposits are well-known, but most of them have yet to be proved. Iron ore, Manganese ore, Bauxite, Limestone, Dolomite, Chromite, Coal and Graphite constitute the most important deposits. Of secondary importance are the deposits of Fire-clay, Refractories, China clay and Ochre.

Iron ore.

Occurrences yielding colossal tonnage of iron ore are found in Mayurbhanj, Keonjhar, Bonai and Bastar states; and in Singbhum, Drug and Chanda districts. According to the estimate of the Geological Survey of India, the total reserves of iron ore in Singbhum, Keonjhar and Bonai states are over 2,000 million tons. In Bastar state the Bailadila occurrence may be well over 600 million tons, while another occurrence in the northern part of the state may approximate 200 to 250 million tons. Iron ore in the Drug district is said to approximate 114 million tons with iron content ranging from 66 per cent. to 69 per cent., the average being 67.6 per cent. With these reserves aggregating 2,500 to 3,000 million tons, there is every likelihood of obtaining large quantities of high grade iron ore, having low phosphorous and silica contents, suitable for electric smelting.

Manganese ore.

Large quantities of manganese ore are found in Keonjhar and Bonai states and in the Central Provinces. Most of the ore from the Keonjhar state is at present being exported at very low rates.

Limestone and dolomite.

Limestone and Dolomite are found in abundance in Sambalpur district, Central Provinces and Gangpur state. The limestone found at Dungri in Sambalpur district (within 30 miles from the Hirakud Dam site) is suitable for the manufacture of cement.

Bauxite.

Extensive deposits of Bauxite are said to occur in Rewa state, at Lohardaga in Ranchi district and in Kalahandi state.

Coal.

Coal is available in considerable quantities at places indicated in Plate II. A number of these deposits have, however, yet to be proved. Coking coal required for steel industry is available in Jharia coal fields and possibly in Rewa and Surguja states.

Graphite.

There are several occurrences of Graphite near Sambalpur which will be of use for lubricants and in the manufacture of carbon electrodes, crucibles and also in foundry.

Forests.

Sambalpur district and the adjoining states are noted for their dense and rich forests. Bamboos and grasses suitable for the manufacture of paper also occur in abundance.

INDUSTRIES**Iron & steel industry.**

With cheap electricity available from the Hirakud Dam, and limestone and dolomites occurring close by, the setting up of an Iron and Steel Factory at Sambalpur should be an economic undertaking. Coking coal will have to be brought from Jharia or possibly from Rewa. It will, however, be possible and even desirable to do away with coal and have recourse to electric smelting and the use of wood charcoal (which will be available in abundance from the forests of Orissa). High grade pig-iron and steel can be produced with electric smelting and the use of wood charcoal instead of coking coal. Sweden, where coal is scarce and water power and forests plentiful, has taken to electric smelting and the use of wood charcoal with excellent results. With the availability of alloy materials, there should be a great future for the manufacture of ferro alloys such as ferro-manganese, ferro-chrome, ferro-vanadium and ferro-titanium in the neighbourhood of Sambalpur.

The iron and steel industry will provide a steady and very substantial load for the Hirakud Power Station.

Aluminium industry.

In the manufacture of aluminium, which takes 10 to 15 times the amount of electric power used in other heavy industries, the cost of power is of vital importance. Aluminium plants are, therefore, located at or very close to the site of power generation. The Hirakud dam site, with the cheap power available there, will afford an ideal location for an aluminium factory. All transmission costs and losses will thus be saved. Bauxite can be brought from Lohardaga in Kanchi district or from Rewa state, the distance by rail from the two quarries being 331 and 222 miles, respectively. Coal is available within 30 miles of the dam site.

The aluminium industry will take a big block of the power generated at the Hirakud Dam. A plant with 15,000 tons annual output of aluminium will require 35,000 to 40,000 k.w. of power.

Paper industry.

Like Sweden and Canada, Orissa has large forests with woods, bamboos and grasses suitable for the manufacture of pulp and paper. Large quantities

of bamboos and grasses are being exported at present to the paper mills outside the province.

Paper manufacture constitutes an important industry in Sweden and is one of the major purchasers of power. In 1932 it took 455 million k.w.h. out of a total of 1,595 million k.w.h. or 29 per cent. of the total power output of Sweden.

In Canada, paper industry produces annually $4\frac{1}{2}$ million tons of paper, about 94 per cent. of which is exported. Its consumption of power in 1944 was 6,118 million k.w.h. The production of a ton of paper per day in Canada requires an installed capacity of 100 h.p.

The pulp and paper industry in Canada provides the greatest industrial peace-time market for the power produced by Central Electrical Stations, as it ordinarily purchases more than 40 per cent. of all the power sold for industrial purposes. During the war years this percentage has been reduced to less than 25 per cent. due to the diversion to munitions production of great amount of power formerly used by the pulp and paper industry. The total installed capacity for the pulp and paper mills is nearly 2 million h.p. and for the electric boilers $1\frac{3}{4}$ million h.p. or a total of $3\frac{3}{4}$ million h.p. out of a total installed capacity in Canada of 10.284 million h.p.

As in Canada and Sweden, paper industry will take large blocks of power from the Hirakud power station and later from the Tikarpara and Naraj stations.

Cement industry.

With limestone suitable for cement manufacture, and shales and coal occurring in large quantities within 30 miles of the dam site, and cheap power available at the dam, a cement factory can be set up there, which will supply not only the cement required for the construction of the Hirakud (possibly half a million tons) and subsequently the Tikarapara and Naraj dams, but also the cement required for other purposes in Orissa and adjoining Provinces. The cement manufactured at Hirakud can be cheaply transported by river and by sea to Bengal and Madras.

Fertilisers.

With irrigation facilities made available by the construction of the Hirakud Dam, the food production of the Sambalpur district and Sonepur state will be materially increased. A further increase will be possible by the judicious use of fertilisers. With cheap power available from the dam, fertilisers can be economically manufactured at Sambalpur for local use as well as for export. There is also the possibility of manufacturing phosphates and many nitrogen compounds.

Other industries.

Several factories can be set up for the utilisation of the forest wealth of Orissa namely, saw-mills for timber, wooden sleepers for railways, etc., plywood factory, tanning factory to make use of the barks of suitable trees, factories for shellac, resins, gums and pharmaceutical products and for wood furniture and cane products.

When large quantities of wood are being burnt for the manufacture of charcoal required for the smelting of iron ore, wood distillation bye-products like alcohol and acetates, can be obtained.

Industries depending on agricultural produce.

With systematic canal irrigation, jute and sugar cane can be grown. Cotton is also likely to be grown on a considerable scale, where suitable soil is available. Jute and sugar mills are, therefore, within the scope of the general industrial development of Orissa. If sufficient cotton is grown a ginning factory is also likely to be set up.

The province of Orissa has been allotted four textile mills to be set up at different places. With cheap power available from the dam, with cotton grown in the irrigated area of the district, and additional quantities brought from the adjoining cotton producing areas of Central Provinces, and with the advantage of a navigable river, Sambalpur should be an ideal site for establishing a textile mill. Tasar and pulp suitable for rayon will form an additional feature of development of the textile mill.

An industry for the manufacture of soap from the vegetable oils and oil from *mahua* seeds may also be started.

Paddy constitutes the main crop in the Province. With cheap power, several rice mills may be set up in convenient localities like Sambalpur, Bargarh and other places including the delta.

Metal industries.

Sheet aluminium obtained from the manufacture of aluminium can be used for establishing an industry run by power for the manufacture of aluminium utensils. Brass and copper sheets can be obtained from the Indian Copper Corporation situated at Maobhandar near Ghatsila about 230 miles from Sambalpur towards Calcutta. An industry for making brass and copper ware can be started. The manufacture of bare and insulated copper wire for electrical purposes is another possibility.

Cottage industries.

Hand-made cloth is finding a big sale in Orissa and the adjoining territories. If cheap power is supplied, power looms can replace handlooms and thus encourage cottage industries and add to the earnings of the people. Matting industry from the long and staple grasses and fibres offers considerable scope.

Salt industry.

Recent investigations indicate the possibility of setting up a major industry for the manufacture of salt in Orissa, particularly in the Chilka Lake. It will be possible to reduce the quantity of fresh water flowing into the lake thereby gradually increasing the density of the brine and helping the manufacture of salt in large quantities.

The Swedish parallel.

¹ The following extracts from "Sweden Power and Industry, 1933" (pages 10 and 14) will be of interest :

"The three fundamental assets on which Sweden's industry has been built of old, are iron ore, forests and water power. Ore, timber and products thereof are the barter goods with which Sweden pays for its import of raw material and commodities from other countries. Of these Swedish export products wood, wood pulp and paper come in for about 50 per cent., iron ore and other ores for about 10 per cent. and iron, steel and semi-finished products thereof for another 10 per cent."

“Owing to the fact that Sweden is poor in fossil fuel but in respect of its resources of water power one of the most fortunately situated countries in Europe, water power assumes a proportionately great importance. Since times immemorial the Swedish mining industry has based its work on water power. Where formerly a modest forge with a water driven hammer was situated you will now often find a modern iron factory, the history of which in many cases goes back through centuries, almost into the dim realm of the Saga. Sweden's ‘White Coal’ has been one of the fundamental factors in the growth of the industrial activity of the country.”

Orissa has all these and much more. It has double the population of Sweden and the power potential of the Mahanadi river alone is almost as big as the entire power potential of Sweden. The Mahanadi also provides a waterway extending from the Central Provinces to the sea with great navigation potentialities. It will permit cheap water transport for the industrial and agricultural produce of its valley to local and foreign markets.

With planned utilisation of its natural resources, Orissa can be as great in the industrial field as Sweden. The construction of the Hirakud dam will mark the beginning of the industrial era in this Province.

CHAPTER XV.

DESIGNS.

Due to the shortage of staff, it has not been possible to prepare detailed designs. Tentative designs have, however, been prepared and for purposes of estimates, kept on the conservative side.

THE DAM.

It is proposed to construct the dam across the main channel partly of masonry and partly of earth and rock materials. The section on the right will be in masonry and will contain the spillway, sluices, powerhouse, navigation locks, fish ladder and timber shoot. The length of this part of the dam will be approximately 5,000 ft. The rest of the dam across the main channel will be of earth and rock materials of the rolled-fill type.

The question as to whether the dam across the whole of the deep channel should be exclusively of concrete or part concrete and part rolled-fill, is under further examination both from the structural and economical view points. Preliminary studies indicate that the proposed combination of masonry and rolled-fill dam in the deep section will secure maximum economy with absolute safety.

Large and high earthen dams have been constructed in other parts of the world. The Anderson Ranch in the U.S.A. which has been recently completed is 400 ft. high and is made up of rolled-fill earth and rock materials. In the Punjab, weirs and barrages have been constructed for flood capacities ranging from 650,000 to one million cusecs. Their spillway sections range from 3,000 to 5,000 ft. in length and are flanked by marginal earthen embankments 15 miles or more in length and 10' to 40' in height.

Concrete section.

The concrete part of the dam has been designed as a gravity section with provision for a hydraulic jump bucket in the spillway section. (See Plate XII).

Spillway.

The design of the spillway is tentative. Various alternatives are under examination. These are (i) overflow spillway with drum gates, (ii) overflow spillway with rising gates or sector gates, (iii) no overflow and all floods to be discharged through deep set sluices as in the case of the Aswan Dam on the Nile in Egypt, (iv) Ganesh Iyer Volute Siphons with inlets placed as close to bed level as possible; or a combination of two or more of the above alternatives. Ganesh Iyer Volute Siphons have some unique advantages. They have no moving parts; they can draw water from the bottom of the pond, thus discharging a good deal of the silt load carried by the flood waters; the regulation is simple and automatic. A combination of these siphons and deep set sluices may work out to be the most effective design for silt exclusion and possibly the most economical. The estimates of cost are based on what is considered to be the most expensive, though equally satisfactory alternative, *viz.*, alternative (i) with drum gates.

Large scale model experiments will be carried out in respect of the various alternatives. The final design will be based on the result of these experiments with due regard to considerations of economy, tail erosion, silt discharging capacity and effective flood regulation.

Earthen section.

The section of the Earthen Dam is proposed to be of the conventional type used in the Bureau of Reclamation (U.S.A.) which consists of an impervious zone in the middle, supported by semi-pervious and pervious zones on either side with suitable stone protection (See Plate XII). Sand cores will be introduced as protection against white ants, if so indicated by experiments.

A soils laboratory is being set up at the dam site to make a comprehensive study of the earth materials in the various borrow pits with a view to determine their suitability for use in the dam.

Dykes.

The dykes on either bank will be constructed of rolled-fill earth and rock materials. Their design will generally follow the design of the earthen dam across the deep channel section.

POWER HOUSE.

Provisional designs have been made on the analogy of existing structures of similar type. Detailed designs will be taken up as staff becomes available.

NAVIGATION LOCKS.

A lumpsum provision has been made for this purpose. The design of the navigation locks will be finalised when the results of the further surveys of navigation possibilities of the Mahanadi, which are in progress, are known.

POWER CANAL.

The Power Canal has been designed to carry a discharge of 18,000 cusecs. In case it is found necessary, later on, to increase the capacity of this canal to carry additional regulated supplies made available by the construction of dams higher up the Mahanadi, it will be possible to do so with the 5 feet free-board that has been allowed in the design.

TAILRACE.

The Power Canal is designed to run steady supplies as the upper power house will be run as a base load station. The tailrace will carry the fluctuations in water due to fluctuating loads in the lower power house. The tailrace will be designed for the full discharge but as the load will come on gradually only part of the section will be excavated, leaving the rest to be done by the running water as far as possible.

HEAD REGULATORS & PUMPING STATIONS.

The design of Head Regulators and Pumping stations will follow conventional practice, and will be taken up when construction is authorised.

IRRIGATION CHANNELS.

The Irrigation Channels have been designed on conventional lines. The detailed designs of individual canals, distributaries and masonry structures will be taken up when the Project receives sanction.

CENTRAL DESIGNS ORGANISATION.

It is proposed to set up a Central Designs Organisation in the Central Waterways, Irrigation and Navigation Commission. This organisation will be entrusted with the detailed designs of the Hirakud Dam Project and later with those for the Mahanadi River Valley Development as a whole.

CHAPTER XVI.

PROGRAMME OF CONSTRUCTION AND ESTABLISHMENT.**PROGRAMME OF CONSTRUCTION.**

It is proposed to complete the Hirakud dam with its dykes and subsidiary dam, the two power houses, the power canal and the main canal system in a period of five to six years.

The details of programme are being worked out along with the details of design. The tentative programme is given by years in Appendix XV and is generally described below:

Surveys and investigations.

These are in progress. The topographical surveys for the canal system and areas to be irrigated will be completed by the end of March 1949. Finished survey sheets will be made available as the work on them is completed. Thus the work of laying out of channels and their excavation can proceed uninterrupted. Exploratory work by means of diamond drills and calyx drills will be taken in hand in about a month's time and completed possibly within one year. The investigations about mineral deposits and industrial possibilities have been started and will continue for a number of years.

Tools and plant.

A certain amount of heavy tools and plant has already been procured from the Disposals and a part of it will be diverted to this project as soon as its construction receives sanction. Order for the balance will be placed at the same time.

Road and railway.

Construction on these will begin and be completed during the first year of construction.

Buildings.

The construction of most of the buildings for the dams and appurtenant works will be completed in two years. But the work on buildings for the canals may extend to a further period of two years.

Cement manufacture.

A new factory will be set up at Sambalpur, and order for it must be placed immediately the project receives sanction. It will take about 18 months from the date of placing the order to the date the cement manufacture actually begins. In the interval, cement will be obtained from existing factories, but the main programme of concrete will begin only when the new factory becomes operative. This will result in large savings which may pay for a major part of the cost of the factory.

Land acquisition.

In the first year of construction land will be acquired for road, railway, buildings and for the actual dam, dykes, power canal and tailrace; also for part of the canals. No land will be acquired for the reservoir area in the first and second years. The bulk of the land for the reservoir area will be acquired in stages from the third to fifth year.

During the first two years, new lands will be prepared for the settlement of dispossessed people to the extent of about one-third of the total requirements. The balance two-thirds will be prepared in the third and fourth years. The programme of construction of model villages will be undertaken simultaneously with the preparation of new lands in accordance with the general plan and policy approved by the Government.

Land for canals and distributaries will be acquired by stages extending over four years.

Work-shop, power house and cement and soil-research laboratory.

The construction of a fully equipped workshop, power-house and a field research laboratory for concrete and soils will be started immediately the project receives sanction.

Dams and dykes.

In the first year work will be started on the dykes, the main earthen dam over the Hirakud island and the preparation of foundations for the power house and navigation locks. Some work will also be started on the subsidiary dam for the balancing reservoir and the preparation of foundation for the lower power house. In the second year work will begin on the preparation of foundation for the concrete part of the dam. The exact programme of concreting and of building up earthen embankment will be carefully considered in detail so that, as the concrete section rises in height, the earthen part of the dam is always well above the anticipated flood afflux caused by the increasing height of the concrete part of the dam. The earth dam and dykes will be finished in four years. The concrete part of the dam will lag by one year. Generally speaking, there will be eight working months in the year, but certain parts of the work will continue as far as possible during the monsoon. The details of diversion of the river in relation to the programme of earthwork and concreting are under preparation.

Spillway gates will be installed and made fit for operation by the end of the fifth year.

Power house.

The programme of construction of the two power houses will be so arranged that in the fourth year the first set of units can be installed.

Power canal.

The Power Canal and the tailrace will be completed in the third year. The locks will be constructed about the same time.

Generating units.

The programme of erecting the various units will depend upon the time taken by the manufacturers to produce them. From preliminary enquiries it appears that it will be possible to obtain the first consignment of power unit in the fourth year. On this basis and the assumption that the power load will develop as anticipated, it is proposed to instal 2 units of 25,000 k.w. in the fourth year, 2 units each in the fifth, sixth, seventh, tenth, twelfth and fifteenth years, completing the installation of the entire 350,000 k.w. by the fifteenth year. A certain amount of adjustment in the programme may be necessary to suit the growth of load, but according to the above programme six units of

25,000 k.w. each will have been installed in the upper power house and 8 units of the same capacity in the lower power house by the fifteenth year.

Canals and head regulators.

As soon as the final alignment of any section of the main line has been marked on the ground and land acquired, excavation of earth and construction of masonry works will be taken up. The progress in the first year will be nearly half of that in the subsequent years. It is proposed to complete the entire work in five years. The Head Regulators of canals will be constructed during the first three years.

Transmission lines.

The first transmission line to be put in will be the one connecting the upper and lower power houses. The next in order will be the subsidiary transmission line to the pumping stations. This will be followed by the 132 K.V. transmission lines to Jharsuguda and Cuttack. Then will follow the link to the Machkund power station. Other transmission lines will be erected as need arises. The programme will be more or less as follows: By fourth year connecting two power houses, pumping stations and Jharsuguda; by fifth and sixth year connecting Jainshedpur and Cuttack, also balance of pumping stations; by seventh and eighth year connecting Duduma (Machkund) power station.

Installation of pumping plants

It is proposed to have all the pumping plants installed between the fourth and sixth year by which time it is hoped that the necessary machinery will be available.

Soil analysis.

This work has already been started and will continue for four to five years. This will be necessary for the planning of the development of irrigation as well as the crop rotation. It will be most important in the initial stages when lands for the settlement of dispossessed people are being reclaimed.

Model experiments.

Model experiments for the various features of the dam and appurtenant works will be taken in hand in the first year and will continue as necessary throughout the course of construction.

ESTABLISHMENT.

The details of establishment required each year after the start of construction are given in the schedule of establishment in Appendix XV.

Design work.

All design work for the project will be done by the **Central Designs Organisation** which is being set up in the Central Waterways, Irrigation and Navigation Commission.

Model experiments.

All model work and all large scale concrete and other researches will be carried out by the Central Waterways, Irrigation and Navigation Research Stations at Delhi and Poona.

No separate provision has been made for establishment required for design, research or model work as such provision already exists in the two organisations for design and research.

Direction.

The entire work of construction will be under the administrative charge of an officer of the rank of a Chief Engineer (to be designated as Chief Engineer or Engineer-in-Chief) who will work under the general direction of the Central Waterways, Irrigation and Navigation Commission.

The Chief Engineer will be assisted by a Personal Assistant of the rank of Executive Engineer and will have the full complement of office staff.

The additional staff required for this work in the Central Waterways, Irrigation and Navigation Commission will consist of two Assistant Secretaries, one for works and one for establishment, assisted by Office Superintendents and the usual office staff.

Superintendence.

Under the Chief Engineer there will be four Superintending Engineers, in charge of Dams and appurtenant works, Canals, Electrical I and Electrical II. The last will be appointed in the second year.

Executive..

There will be three to four divisions to each circle and on the average four sub divisions to each division. In addition each Superintending Engineer will have a Personal Assistant of the rank of Assistant Executive Engineer.

The various divisions and sub divisions will be opened by stages to suit the progress and programme of work.

Besides the Engineer Officers there will be Specialist Officers, like Geologists, Medical, Health, Welfare and Malaria Control and Forest Officers.

Recruitment.

There is likely to be considerable difficulty about the full recruitment of staff of the required categories. It is believed that suitable Superintending Engineers and some Executive Engineers will be available from the Services, but the bulk of Executive Engineers and Sub Divisional Officers will have to be recruited from the open market, and from among freshes from colleges with or without construction experience. The difficulties in recruitment in respect of quality and numbers may affect the programme of works, but it is felt that no serious delays need be anticipated on this account.

Maintenance.

When construction is completed, the direction of the dam and canals will pass to the Chief Engineer, Irrigation Works, Orissa and of the Power Houses and transmission lines to the Chief Engineer, Electricity, Orissa. The strength of circles and divisions will then be as follows:

Superintending Engineer, Dam & Canal System	..	..	1
Superintending Engineer, Electrical	..	..	2
Executive Engineer, Dam	..	..	1
Executive Engineer, Canals	..	..	3
Executive Engineer, Mechanical	..	..	1
Executive Engineer, Power House	..	..	2
Executive Engineer, Transmission lines	..	..	3 to 4
Sub Divisional Officer, 3 per division	..	..	33
Shift Engineers	..	..	8

The above with due allowance for leave reserve will constitute the permanent increase in the Engineering Cadre of Orissa. The electrical staff will have to be further increased as the load increases to full capacity of the Power House. Additional electrical staff will be required if the Government undertakes to do local distribution.

CHAPTER XVII.

ESTIMATE OF EXPENDITURE.

The estimates of expenditure anticipated on the Hirakud Dam, appurtenant works, canals and hydel installations have been worked out in some detail and are abstracted in Appendix XIV. Brief details are given below:—

1. DAM AND APPURTENANT WORKS.**I. Works.****A. Preliminary.**

This comprises cost of preliminary surveys and investigations, temporary buildings, camp equipage, trial borings and tools and plant, and includes a lump sum provision of Rs. 4 lakhs for aerial and ground surveys of the reservoir area, Rs. 6 lakhs for the exploratory work on foundations to be done by means of diamond and calyx drills, Rs. 1 lakh for preliminary investigations to find out suitable earth and concrete materials. The total provision under this head is Rs. 15 lakhs.

B. Land.

The reservoir will submerge an area of 135,000 acres of which nearly 70,000 acres is cultivated. A sum of Rs. 5 crores has been provided to cover the cost of this and other land required for the works, and of the houses, wells, tanks and trees standing on it. A reference is invited in this connection to Chapter VII and Appendix XIII.

C. Works.

The total provision for the concrete and earth sections of dam and the dykes is Rs. 7.44 crores. It includes a sum of Rs. 65 lakhs for preparation of foundations, drilling, grouting of holes, driving sheet piles under the earthen dam or alternatively for carrying the impervious core down to the bed rock. The figures of cost of concrete and earth dams are based on detailed estimate, but a lump sum provision of Rs. 25 lakhs has been made for the stilling basin, fish ladder, timber shoots, etc.

D. Spillway.

The total provision under this head is Rs. 1.3 crores. For purposes of this estimate it has been assumed that drum gates will be used, but various other alternatives are under consideration particularly the use of Ganesh Iyer Volute Siphons.

K. Buildings

A lump sum of Rs. 25 lakhs has been provided under this head for both permanent and temporary buildings.

M. Plantations.

A provision of Rs. 1 lakh is made for planting avenue trees in the colony, parks and elsewhere in the dam area.

O. Miscellaneous.

The provision of Rs. 37.5 lakhs made under this head includes cost of 10 miles of approach road from Sambalpur and bridges, and 12 miles of the broad gauge railway line from Sambalpur rail head of the B.N. Railway. It also provides for malaria control measures, sanitation and medical aid, etc. An amount of Rs. 50,000 is provided for the opening ceremony.

P. Maintenance.

The usual per cent. of works outlay is provided for maintenance of works during the construction period.

6. Special Tools and Plant.

A lump sum provision of Rs. 50 lakhs is made under this head. This will include the cost of concrete mixers, dragline excavators, bulldozers, rollers, crushers, air compressors, cranes and all heavy machinery required for the construction of the project.

II. Establishment.

On canal works the cost of establishment ranges between 7 per cent. to 10 per cent. On the dam, the work is very much concentrated and costly, and machinery forms a great part of it and so a provision of 5 per cent. on works will, it is considered, be sufficient.

Leave and pension allowances have been calculated at 21 per cent. on cost of establishment.

III. Tools and Plant.

This has been allowed at 1 per cent. on works excluding cost of land.

IV. Suspense.

Nil.

V. Receipts on capital investments.

Heavy tools and plant will have a residual value after the completion of construction. This has been taken as 30 per cent. of the original cost. Other miscellaneous income has been taken as Rs. 1 lakh. The total receipts will come to Rs. 16 lakhs.

VI. (1) Capitalisation of abatement of land revenue.

The annual land revenue for the submerged area is about Rs. 40,000. As usual the capitalised value of this has been taken at 20 years rental.

VI. (2) Audit charges

This has been taken as 1 per cent. on works outlay.

2. MAIN CANALS & BRANCHES.**I. Works.****A. Preliminary.**

Under this head provision has been made for the survey of 1,400,000 acres by the Survey of India and detailed survey by the CWINC. In addition a survey of the soil in the irrigated area is necessary to decide about the suitability of the land for irrigation, for which a lump sum of Rs. 1,00,000 is provided.

B. Land.

The area of land required for each channel has been worked out from typical cross sections prepared for different depths of cutting and heights of embankment. The average rate of land has been taken as Rs. 200 per acre. The total expenditure on this account works out to Rs. 16 lakhs.

D. Regulators.

A provision of Rs. 8,10,000 is made under this head for construction of head regulators of canals taking off from the reservoir as well as of head regulators of distributaries taking off from the canals. Detailed estimates have not been worked out.

E. Falls.

A provision of Rs. 3,60,000 has been made under this head.

F. Cross drainage works.

The canals will have to cross a number of natural drainages and a provision of Rs. 29,60,000 has been made for this purpose.

G. Bridges.

A provision of Rs. 21,10,000 has been made under this head for bridges on canals for trunk roads, district roads and village roads.

H. Escapes.

Escapes will have to be provided on all main canals at suitable points for disposing of excesses, and a provision of Rs. 1,60,000 has been made for this purpose.

K. Buildings.

A sum of Rs. 15,00,000 is provided under this head for construction of residential buildings for officers, subordinates and other staff, in addition to inspection bungalows for touring officers. The amount includes both permanent and temporary buildings required for the period of construction.

L. Earthwork.

Detailed estimates have not yet been worked out for this item. The cost of earthwork is based on typical cross sections for different depths of channels by reaches. A provision of Rs. 4 crores has been made under this head.

M. Plantations.

A lump sum provision of Rs. 1,00,000 for planting avenue trees on both sides of the channels is made.

O. Miscellaneous.

Under this head, a provision of Rs. 2,00,000 is made for fixing of boundary pillars, bench marks and for the improvement of existing roads. Detailed figures for pumping plant and machinery have not been worked out, but a sum of Rs. 1 crore, has been provided for pumping plant for lift irrigation on the basis of preliminary enquiries.

P. Maintenance.

A provision of 1 per cent. of total cost under all sub heads has been made to cover this item. This works out to Rs. 5,80,000.

6. Special tools and plant.

of Rs. 300,000 *special*
Provision ~~at 1 per cent. on the cost of works~~ is made for tools and plants.

II. Establishment.

Provision for establishment has been made at the rate of 10 per cent. of cost of works; 21 per cent. of the cost of establishment has been added to cover pensionary charges and leave salary. The total provision on the above basis works out to Rs. 72,12,000.

III Tools and plant.

Provision at 1 per cent. on the cost of works has been made.

VI(1) Capitalisation of abatement of land revenue.

This represents the capitalized value of the loss of land revenue on land proposed to be acquired for the project and has been taken as twenty times the annual loss. It works out to Rs. 1,86,000.

VI(2) Audit charges.

A provision of Rs. 5,00,000 is made for this item, which is nearly 1 per cent. of the cost of works.

3. DISTRIBUTARIES.

Provision for distributaries has been made on acreage basis for the cultivable area covered by the project. A rate of Rs. 8/- per acre has been allowed; the corresponding rates for recent constructions in India vary from Rs. 6.03 to 10.71 per acre. The total cost works out to Rs. 70 lakhs.

5. WATER COURSES.

Cost of water courses will be recovered from the cultivators as usual, but a provision on acreage basis at the rate of annas 8 per acre on total cultivable area is made to meet any expenditure in this connection, which cannot eventually be recovered from the cultivators. It works out to Rs. 4,38,000.

3. HYDRO-ELECTRIC INSTALLATIONS.**CIVIL WORKS.****I. Works.****A. Preliminary.**

A small sum of Rs. 10,000 has been provided under this head for any preliminary works that may be necessary.

B. Land.

A provision of Rs. 21 lakhs has been provided for acquisition of land required for power channel, tailrace channel, and land and property to be submerged under the subsidiary reservoir.

C. Works.

This head includes excavation of power channel, tail race channel, and construction of a subsidiary dam and escapes. Quantity of earthwork has been worked out in detail, but an extra sum of Rs. 50 lakhs has been included for blasting of rocks for the power channel. A lump sum of Rs. 3 lakhs is also provided for escapes. Total provision under this head is Rs. 4 crores.

K. Buildings.

A provision of Rs. 70 lakhs is made under this head to cover the cost of construction of buildings for the two power houses, the switch yards and the residential quarters for the electrical staff.

O. Miscellaneous.

A provision of Rs. 10,000 is made.

Unforeseen.

A provision of Rs. 49 lakhs has been made for unforeseen works, as complete details of all requirements could not be worked out during this short period.

II. Establishment.

A total provision of Rs. 29,72,000 has been made at 5 per cent. on cost of works for establishment and 21 per cent. of the cost of establishment for their pensionary and leave charges.

III. Tools and plant.

A provision of Rs. 4,91,000 has been made on basis of 1 per cent. of the total cost of works.

VI(2) Audit charges.

A provision of Rs. 5 lakhs is made for audit charges which is nearly 1 per cent. of the cost of works and establishment.

ELECTRICAL EQUIPMENT.

It has not been found possible to work out the detailed cost of electric plant and installations: and so costs for different items provided in the estimate are on basis of preliminary enquiries made from different sources.

A. Power generation.

Provision has been made at Rs. 300 per k.w. which works out to Rs. 10,50,00,000 for 350,000 k.w. installed capacity.

B. Transmission.

The provision includes cost of transmission lines to Jharsuguda, Tatanagar and Cuttack and connection between two power houses. It also includes part cost of line towards Duduma. Total cost of all these transmission lines as provided is Rs. 3,55,00,000.

C. Transformation.

A lump sum of Rs. 3 crores is provided for all the sub stations as complete details cannot be worked out at this stage.

NAVIGATION.

Since detailed drawing and estimates have not yet been prepared, a lump sum provision of Rs. 1 crore has been included for the construction of two sets of locks required at the falls in the power channel.

CHAPTER XVIII. FINANCIAL RESULTS.

ESTIMATES OF EXPENDITURE.

The project consists of four major units, viz.,

- (i) Dam and appurtenant works.
- (ii) Main canals, branches, distributaries and water courses.
- (iii) Hydro Electric Installations, and
- (iv) Navigation.

Detailed estimates of costs are given in Appendix XIV and explanatory notes are given in Chapter XVII.

PROGRAMME OF WORKS EXPENDITURE.

The programme of construction is outlined in Chapter XVI and Appendix XV. Based on this programme, the probable expenditure on works, by years, for the different units is given in part I of the financial statements.

Part II gives a summary of direct charges to the capital account. This includes works outlay from part I, establishment, leave and pensionary charges and cost of tools and plant. Necessary deduction on account of probable receipts on capital account has been made.

Part III gives a summary of indirect charges to capital, and includes the capitalised abatement of land revenue and charges for audit and accounts.

REVENUE (IRRIGATION)

Direct revenue from irrigation.

Details of water rates to be charged for different crops are dealt with in Chapter X and Appendix VIII. In addition to the usual irrigation by flow, it is proposed to serve highlying areas by means of lift irrigation. To meet the extra cost involved in lifting irrigation water, it is proposed to charge an additional flat rate of Rs. 1|8/- per acre on the entire area irrigated by lift.

The average water rate for flow irrigation is Rs. 3.77 per acre, and that for lift irrigation will thus be Rs. 5.27 per acre.

The details of anticipated direct revenue from irrigation are given in part IVa. Irrigation will start from the fourth year after commencement of construction and in the seventh year, by which time all the channels and works will be completed, it is anticipated that 50 per cent. of the project area will receive irrigation. Thereafter the area under irrigation will increase every year until by the fifteenth year the entire project area is expected to receive irrigation.

Indirect Revenue.

The total irrigable area under the project will be 875,210 acres. As stated in Chapter X, it is proposed to increase the rent of all lands by an average rate of Rs. 2 per acre. The revenue under this head is given in part IVb.

Revenue from lease of waste lands.

The statement on page 55 Chapter X shows the extent of marginal lands in the reservoir area which will become available each year for cultivation with the depletion of the reservoir. For purposes of revenue forecast it has been assumed that 20,000 acres will be available each year and, at an annual lease rate of Rs. 4 per acre, Rs. 80,000 will be the annual revenue—vide col. 4 of part IVc.

Working expenses.

For the maintenance and operation of canals a flat rate of Rs. 1-12-0 per acre irrigated has been assumed.

Lift irrigation involves not only the maintenance of the usual canal and distributary system, but also the cost of electrical power used in pumping, depreciation of pumping plant, and the cost of their maintenance and operation. A rate of 1.66 per cent. on the capital cost for depreciation, and 1.5 per cent. for maintenance and operative charges, has been allowed on the capital cost of Rs. one crore for the pumping plant. The cost of energy for electric pumping works out to Rs. 12 lakhs.

The gross revenue, the working expenses and the net revenue from irrigation are shown in part IVc.

REVENUE (POWER)

Development of load.

Electric energy will be available both for pumping and other loads in the fourth year from the date the construction starts. The installed capacity and the peak load capacity available, allowing for standby, are given in part Va.

Out of the peak demand, after utilising the power required for pumping irrigation water depending on the area to be irrigated, balance would be available for industries. It is assumed that the development of industrial load will keep pace with the development of peak load capacity with a lag of one year for half the load and two years for the full load.

Rate structure.

The average rate per k.w. of peak demand per year will gradually drop with the progressive rise in load from Rs. 160 for an installed capacity of 100,000 k.w., to Rs. 150 for 150,000 k.w., to Rs. 120 for 200,000 k.w. and to Rs. 100 for 350,000 k.w. For pumping load the rate per k.w. per year of peak demand will be kept uniform at Rs. 20 per k.w. year.

Working expenses.

The rates of depreciation, and maintenance and operation, are given in detail in Appendix IX. Depreciation has been allowed at the rate of 2.75 per cent. on transmission lines and 1.66 per cent. on generation. For maintenance and operation 1.5 per cent. has been allowed on the total capital cost including the portion of the cost of dam, power house, power channel, and tail-race allocated to power.

Details of gross revenue from power, working expenses, and net revenue are given in parts Va and Vb.

REVENUE RETURNS

Part VI gives the total net revenue both from power and irrigation.

When the project fully develops the gross revenue from irrigation will be Rs. 66.71 lakhs. Deducting the working expenses of Rs. 34.32 lakhs the net revenue will be Rs. 32.39 lakhs. From electrical power, the gross revenue will be Rs. 252 lakhs with a working expense of Rs. 79.81 lakhs. The net revenue will be Rs. 172.19 lakhs. The total net revenue will be Rs. 204.58 lakhs.

Parts VII and VIII give the final financial results of the project. Interest on capital has been taken at the rate of 3 per cent. From part VII it is seen that the project begins to pay from eleventh year, i.e., the percentage return on sum at charge in that year will be 3.22 per cent. In the eighteenth year the accumulated interest on the direct outlay just balances the cumulative revenue up to that year, the percentage return thereafter being 4.29 per cent. gross. There will thus be an annual profit of 1.29 per cent. on the capital or Rs. 61.15 lakhs.

FINANCIAL STATEMENTS

HIRAKUD DAM PROJECT.

FINANCIAL STATEMENTS.

PART I.

Programme of Works Expenditure.

Sub-head	First year 1947-48	Second year 1948-49	Third year 1949-50	Fourth year 1950-51	Fifth year 1951-52	Sixth year 1952-53	Total
1. Dam and Appurtenant Works—							
A Preliminary ..	10,00,000	5,00,000	.			.	15,00,000
B Land	10,00,000	20,00,000	1,50,00,000	1,60,00,000	1,60,00,000	..	5,00,00,000
C (i) Diversion works ..	.	5,00,000	5,00,000	5,00,000	.	..	15,00,000
(ii) Preparation of foundation ..		35,00,000	30,00,000	.	..		65,00,000
(iii) Dams ..	.	1,00,00,000	2,00,00,000	2,00,00,000	1,00,00,000	64,00,000	6,64,00,000
D Spillway ..	.	20,00,000	30,00,000	30,00,000	30,00,000	20,00,000	1,30,00,000
K. Buildings ..	10,00,000	10,00,000	5,00,000	..	.	.	25,00,000
M. Plantations ..	..	50,000	50,000	.	.	.	1,00,000
O. Miscellaneous ..	25,00,000	10,00,000	1,00,000	1,00,000	50,000		37,50,000
P. Maintenance ..	..	.	1,00,000	2,50,000	3,00,000	2,50,000	9,00,000
6. Special tools & plant ..	30,00,000	10,00,000	10,00,000	.	..	.	50,00,000
Total ..	85,00,000	2,15,50,000	4,32,50,000	3,98,50,000	2,93,50,000	88,50,000	15,11,50,000

PART I.

Programme of works expenditure—contd.

Sub-head	First year 1947-48	Second year 1948-49	Third year 1949-50	Fourth year 1950-51	Fifth year 1951-52	Sixth year 1952-53	Total
2. Main Canals, Branches—							
A. Preliminary ..	5,00,000	3,00,000	2,00,000	.	.	..	10,00,000
B. Land ..	2,00,000	4,00,000	5,00,000	3,00,000	1,00,000	1,00,000	16,00,000
D. Regulators ..		..	2,00,000	4,00,000	1,00,000	1,10,000	8,10,000
E. Falls ..	.	..	1,00,000	1,00,000	1,00,000	60,000	3,60,000
F. Cross Drainages ..		2,00,000	3,00,000	10,00,000	8,00,000	4,60,000	29,60,000
G. Bridges ..	..	2,00,000	10 00 000	3,10,000	3,00,000	.	21,10,000
H. Escapes ..	..	..	..	..	1,00,000	60,000	1,60,000
K. Buildings ..	3,00,000	5,00,000	3,00,000	2,00,000	1,00,000	1,00,000	15,00,000
L. Earthwork ..	.	50,00,000	1,00,00,000	1,00,00,000	1,00,00,000	50,00,000	4,00,00,000
M. Plantations ..	..	..	25,000	25,000	25,000	25,000	1,00,000
O Miscellaneous ..	10,000	10,000	50,000	50,000	50,000	30,000	2,00,000
P Maintenance ..	..	.	50,000	1,50,000	1,80,000	2,00,000	5,80,000
Telegraph lines ..	..	1,00,000	1,00,000	1,00,000	1,04,000	..	4,04,000
Pumping plant ..	..	..	25,00,000	25,00,000	40,00,000	10,00,000	1,00,00,000
6 Special tools & plant ..	..	1,00,000	1,00,000	1,00,000	..	..	3,00,000
3 Distributaries ..	..	..	4,00,000	9,00,000	24,00,000	33,00,000	70,00 000
5. Water courses ..	..	..	1 00,000	1 00,000	1 00,000	1,88,000	4,38,000
Total ..	10,10,000	68,10,000	1,61,25,000	1,65,35,000	1,84,59,000	1,05,83,000	6,95,22,000

PART I.

Programme of

Sub-head	First year 1947-48	Second year 1948-49	Third year 1949-50	Fourth year 1950-51	Fifth year 1951-52	Sixth year 1952-53	Seventh year 1953-54
Hydro electric installations—							
Civil works							
A. Preliminary ..	5,000	5,000	.	..	..	..	..
B. Land ^a	3,00,000	18,00,000	.	..	.	..	.
C. Works . .	10,00,000	2,00,00,000	1,90,00,000	.	..	..	.
K. Buildings	10,00,000	50,00,000	10,00,000			.	.
O. Miscellaneous	5,000	5,000	..	..	..	..	..
Electric Equipment							
A. Power Generation	..	..	..	1,50,00,000	1,50,00,000	1,50,00,000	1,50,00,000
B. Transmission	5,00,000	10,00,000	50,00,000	1,30,50,000	1,00,00,000	59,50,000	.
C. Transformation .	..	5,00,000	45,00,000	30,00,000	1,00,00,000	50,00,000	50,00,000
Unforeseen expenses		..		..	.	..	.
Total .	28,10,000	2,83,10,000	2,95,00,000	3,30,50,000	3,50,00,000	2,59,50,000	2,00,00,000
Navigation —	.	20,00,000	50,00,000	30,00,000	..	..	..

PART I

Programme of

Minor Heads	First year 1947-48	Second year 1948-49	Third year 1949-50	Fourth year 1950-51	Fifth year 1951-52	Sixth year 1952-53	Seventh year 1953-54
Dam and appurtenant works	85,00,000	2,15,50,000	4,32,50,000	3,98,50,000	2,93,50,000	86,50,000	.
Main Canals, branches, distributaries and water courses	10,10,000	68,10,000	1,61,25,000	1,63,35,000	1,84,59,000	1,03,83,000	..
Hydro electric installation	28,10,000	2,83,10,000	2,95,00,000	3,30,50,000	3,50,00,000	2,59,50,000	2,00,00,000
Navigation .. ..	..	20,00,000	50,00,000	30,00,000	..	..	..
Total ..	1,23,20,000	5,86,70,000	9,38,75,000	9,24,35,000	8,28,09,000	4,51,83,000	2,00,00,000

works expenditure—contd.

Eighth year 1954-55	Ninth year 1955-56	Tenth year 1956-57	Eleventh year 1957-58	Twelfth year 1958-59	Thirteenth year 1959-60	Fourteenth year 1960-61	Fifteenth year 1961-62	Total
..	..	..	..	..	..	..	..	10,000
..	..	..	..	..	..	..	..	21,00,000
..	..	..	..	..	..	..	..	4,00,00,000
..	..	..	..	..	..	..	..	70,00,000
..	..	..	..	..	..	..	..	10,000
..	..	1,50,00,000	..	1,50,00,000	..	..	1,50,00,000	10,50,00,000
..	..	..	..	..	..	..	..	3,55,00,000
..	..	..	..	..	..	..	..	3,00,00,000
5,00,000	5,00,000	5,00,000	5,00,000	5,00,000	5,00,000	10,00,000	9,00,000	49,00,000
5,00,000	5,00,000	1,55,00,000	3,00,000	1,55,00,000	5,00,000	10,00,000	1,59,00,000	22,45,20,000
								1,00,00,000

works expenditure (Abstract).

Eighth year 1954-55	Ninth year 1955-56	Tenth year 1956-57	Eleventh year 1957-58	Twelfth year 1958-59	Thirteenth year 1959-60	Fourteenth year 1960-61	Fifteenth year 1961-62	Total
..	..	..	..	..	..	..	..	15,11,50,000
..	..	..	..	..	..	..	..	6,95,22,000
5,00,000	5,00,000	1,55,00,000	1,55,00,000	5,00,000	5,00,000	10,00,000	1,59,00,000	22,45,20,000
..	..	..	..	..	..	..	..	1,00,00,000
5,00,000	5,00,000	1,55,00,000	5,00,000	1,55,00,000	5,00,000	10,00,000	1,59,00,000	45,51,92,000

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PART II.

Summary of direct charges to Capital Account.

Year	Works outlay	Establishment	Leave salary and pension @ 21% of establishment.	Tools and Plant	Total direct charges	Less receipt on capital accounts	Net charges
1	2	3	4	5	3	7	8
First year	1,23,20,000	3,90,500	82,105	72,000	1 28,64,605		1,28,64,605
Second year	5,86,70,000	29,73,500	6,24,430	5,03,000	6 27 70,930	10,000	6 27,60,930
Third year	9,38,75,000	48,22,500	9,71,760	6,23,000	10,00,92,260	20,000	10,00,72,260
Fourth year	9,24,35,000	34,96,000	7,35,135	3,86,000	9,70,52,135	20,000	9,70,32,135
Fifth year	8,28,09,000	30,05,000	6,32,725	2,95,000	8,67,41,725	20,000	8,67,21,725
Sixth year	4,51,83,000	11,16,000	2,34,345	1,42,000	4,66,75,345	13,00,000	4,56,75,345
Seventh year	2,00,00,000	..	..	..	2,00,00,000	5,30,000	1,94,70,000
Eighth year	5,00,000	..	..	..	5,00,000	..	5,00,000
Ninth year	5,00,000	..	..	..	5,00,000	..	5,00,000
Tenth year	1,55,00,000	..	..	..	1,55,00,000	..	1,55,00,000
Eleventh year	5,00,000	..	..	..	5,00,000	..	5,00,000
Twelfth year	1,55,00,000	..	..	..	1,55,00,000	..	1,55,00,000
Thirteenth year	5,00,000	..	..	..	5,00,000	..	5,00,000
Fourteenth year	10,00,000	..	..	..	10,00,000	..	10,00,000
Fifteenth year	1,59,00,000	..	..	..	1,59,00,000	..	1,59,00,000
Total	45,51,92,000	1,56,03,500	32,80,500	20,21,000	47,60,97,000	16,00,000	47,44,97,000

Col. 2 is the same as totals of Part I. Col. 3: Figures in this column represents 5% of cost of works in the construction of dam and power channel and power house and 10% on main canal works. Col. 4 is 21% of Col. 2. Col. 5 is 1% of works outlay alone.

PART III.

Summary of Indirect charges to Capital.

Year	Capitalised abatement of land revenue	Charges for Audit and Accounts	Total	Remarks
1	2	3	4	5
First year	20,000	80,000	1,00,000	
Second year	64,000	5,42,000	6,06,000	
Third year	2,80,000	7,84,000	10,64,000	
Fourth year	3 10,000	5,55,000	8,65,000	
Fifth year	3,10,000	4,00,000	7,10,000	
Sixth year	2,000	2,56,000	2,58,000	
	9,86,000	26,17,000	36,03,000	

Col. 2 is 20 times the land revenue or land to be acquired during the year.

Col. 3 represents 1% of the cost of works excluding electrical and navigation works

PART IV-a.
Direct Revenue from Irrigation.

Year	Flow Irrigation			Lift Irrigation			Total revenue
	Total acreage . 619,035 Amount : Rs. 23,32,928			Total acreage : 475,918 Amount : Rs. 25,07,822			
	Percentage of develop-ment	Acreage	Amount in Rs.	Percentage of develop-ment	Acreage	Amount in Rs.	
1	2	3	4	5	6	7	8
First year ..	..	..	..	..	..	..	..
Second year .. ..	..	..	..	..	..	..	..
Third year .. ..	..	..	..	..	..	..	..
Fourth year	10	61,904	2,33,293	10	47,592	2,50,782	4,84,075
Fifth year	15	92,855	3,49,940	15	71,388	3,76,173	7,26,113
Sixth year	25	154,759	5,83,232	25	118,980	6,26,955	12,10,187
Seventh year	50	309,518	11 66 464	50	237 959	12 53 910	24 20 374
Eighth year	60	371,421	13,99,757	60	285,551	15,04,692	29,04,449
Ninth year	70	433,325	16,33,050	70	333,143	17,55,474	33,88,524
Tenth year	75	464,276	17,49,696	75	356,939	18,89,865	36,30,561
Eleventh year	80	495,228	18,66,343	80	380,734	20,06,256	38,72,599
Twelfth year	85	526,180	19,82,989	85	404,530	21,31,647	41,14,636
Thirteenth year	90	557,132	20,99,635	90	428,326	22,57,038	43,56,673
Fourteenth year	95	588,083	22,16,281	95	452,122	23,82,429	45 98,710
Fifteenth year	100	619,035	23,32,928	100	475,918	25,07,822	48,40,750

PART IV-b.
Indirect Revenue from Irrigation.

Year	Flow irrigation				Lift irrigation				Total revenue in Rs.
	494,710 acres				380,500 acres				
	Percentage of develop-ment	Acres	Average rate of land revenue	Amount in Rs.	Percentage of develop-ment	Acres	Average rate of land revenue	Amount in Rs.	
1	2	3	4	5	6	7	8	9	10
First year ..	..	..	..	..	..	..	..	..	..
Second year ..	..	..	..	..	..	..	..	..	..
Third year ..	..	..	..	..	..	..	..	..	..
Fourth year ..	10	49,471		98,942	10	38,050		76,100	175,042
Fifth year ..	15	74,207	Rs. 2-	1,48,414	15	57,075	Rs. 2/-	1,14,150	2,62,564
Sixth year ..	25	123,678	per acre	2,47,356	25	95,125	per acre	2,32,250	4,75,606
Seventh year ..	50	247,355		4,94,710	50	190,250		3,80,500	8,75,210
Eighth year ..	60	296,826		5,93,652	60	238,300		4,51,600	10,50,252
Ninth year ..	70	346,297		6,92,594	70	286,350		5,32,700	12,25,294
Tenth year ..	75	371,032		7,42,064	75	285,375		5,70,750	13,12,814
Eleventh year ..	80	395,769		7,91,536	80	304,400		6,08,800	14,00,336
Twelfth year ..	85	420,504		8,41,008	85	323,425		6,46,850	14,87,858
Thirteenth year ..	90	445,239		8,90,478	90	342,450		6,84,900	15,75,378
Fourteenth year ..	95	469,975		9,39,950	95	371,475		7,22,950	16,62,906
Fifteenth year ..	100	494,710		9,89,420	100	380,500		7,61,000	17,50,420

PART IV-c. Summary of Irrigation Revenue.

Year.	Direct revenue.	Indirect revenue.	Revenue from lease.	Total gross revenue. Cols. 2 + 3 + 4.	Maintenance of distribution system at Re. 1/12/- per acre.	Cost of electric energy for pumping irrigation water.	Depreciation, maintenance & operation of pumping plant at 3-16% of capital cost.	Total working expenses. Cols 6 + 7 + 8.	Net Irrigation Revenue. Col 5-9
1	2	3	4	5	6	7	8	9	10
Fourth year ..	4,84,075	1,75,042	.	6,59,117	1,91,616	1,20,000	79,000	3,90,616	2,68,501
Fifth year ..	7,26,113	2,62,564	40,000	10,28,677	2,87,427	1,80,000	1,58,000	5,25,427	5,03,230
Sixth year ..	12,10,187	4,75,606	60,000	17,45,793	4,79,042	3,00,000	2,84,000	10,63,442	6,82,251
Seventh year ..	24,20,374	8,75,210	80,000	33,75,584	9,58,083	6,00,000	7,16,000	18,74,083	15,01,501
Eighth year ..	29,04,449	10,50,252	80,000	40,34,701	11,49,701	7,20,000	3,16,000	21,85,701	18,49,000
Ninth year ..	33,88,524	12,25,294	80,000	46,93,818	13,41,316	8,40,000	3,16,000	24,97,316	21,96,502
Tenth year ..	36,30,561	13,12,814	80,000	50,23,375	14,37,125	9,00,000	3,16,000	26,53,125	23,70,250
Eleventh year ..	38,72,599	14,00,336	80,000	53,52,935	15,32,934	9,60,000	3,16,000	28,08,934	25,44,001
Twelfth year ..	41,14,636	14,87,858	80,000	56,82,494	16,28,743	10,20,000	3,16,000	29,64,743	27,17,751
Thirteenth year ..	43,56,673	15,75,378	80,000	60,12,051	17,24,429	10,80,000	3,16,000	31,20,429	28,91,622
Fourteenth year ..	45,98,710	16,62,900	80,000	63,41,610	18,20,361	11,40,000	3,16,000	32,76,361	30,53,249
Fifteenth year ..	48,40,750	17,50,420	80,000	66,71,170	19,16,167	12,00,000	3,16,000	34,32,167	32,39,003
Sixteenth year ..	48,40,750	17,50,420	80,000	66,71,170	19,16,167	12,00,000	3,16,000	34,32,167	32,39,003
Seventeenth year ..	48,40,750	17,50,420	80,000	66,71,170	19,16,167	12,00,000	3,16,000	34,32,167	32,39,003

Col. 2 is the same as col. 8 of part IV a. Col. 3 is the same as col. 10 of part IV b. Col. 7 is the same as col. 6 of part Va.

PART V-a. Power Development and Revenue.

Year.	Instal- led Capa- city	Peak Load Capacity	Irrigation load			Industrial load.			Total Revenue	Working expenses (Vide Part Vb) Rs.	Net Revenue
			Peak power required	Rate	Revenue	Peak power	Rate	Revenue			
			k.w.	Rs.	Rs.	k.w.	Rs.	Rs.			
1	2	3	4	5	6	7	8	9	10	11	12
Fourth year (1950-51)	50,000	25,000	6,000	20	1,20,000	7,000*	160	11,20,000	12,40,000	..	12,40,000
Fifth year (1951-52)	100,000	50,000	9,000	20	1,80,000	15,000†	160	24,00,000	25,80,000	17,29,875	8,50,125
Sixth year (1952-53)	150,000	100,000	15,000	20	3,00,000	20,000	160	32,00,000	35,00,000	30,53,875	4,46,125
Seventh year (1953-54)	200,000	150,000	30,000	20	6,00,000	45,000	160	72,00,000	78,00,000	54,07,375	23,92,625
Eighth year (1954-55)	200,000	150,000	36,000	20	7,20,000	89,000	160	1,42,40,000	1,49,60,000	62,86,750	86,73,250
Ninth year (1955-56)	200,000	150,000	42,000	20	8,40,000	108,000	150	1,62,00,000	1,70,40,000	65,59,250	1,04,80,750
Tenth year (1956-57)	250,000	200,000	45,000	20	9,00,000	110,000	150	1,65,00,000	1,74,00,000	65,59,250	1,08,40,750
Eleventh yr. (1957-58)	250,000	200,000	48,000	20	9,60,000	127,000	150	1,90,50,000	2,00,10,000	70,33,250	1,29,76,750
Twelfth year (1958-59)	300,000	250,000	51,000	20	10,20,000	149,000	120	1,78,80,000	1,89,00,000	70,33,250	1,18,66,750
Thirteenth yr. (1959-60)	300,000	250,000	54,000	20	10,80,000	171,000	120	2,05,20,000	2,16,00,000	75,07,250	1,40,92,750
Fourteenth yr. (1960-61)	300,000	250,000	57,000	20	11,40,000	193,000	120	2,31,60,000	2,43,00,000	75,07,250	1,67,92,750
Fifteenth yr. (1961-62)	350,000	300,000	60,000	20	12,00,000	200,000	120	2,40,00,000	2,52,00,000	75,07,250	1,76,92,750
Sixteenth yr (1962-63)	350,000	300,000	60,000	20	12,00,000	215,000	120	2,58,00,000	2,70,00,000	79,81,250	1,90,18,750
Seventeenth year. (1963-64)	350,000	300,000	60,000	20	12,00,000	240,000	100	2,40,00,000	2,52,00,000	79,81,250	1,72,18,750

* Cement, Orient Paper Mills & Local power.

† Above - Cuttack and Orissa Textile Mills.

NOTE.- This rate of development is on the assumption that industrial planning and the setting up of factories will keep pace with the increase in installed capacity. If that does not happen, then the installation of additional units will be delayed. On the other hand, if the aluminium manufacture and interconnection to Tata's Juxity, the load will increase much more rapidly and the installation of plant accelerated.

PART V-b.
Working Expenses for Power.

Generation				Transmission.			Maintenance charges including establishment.			Total working expenses.
Year.	Cost upto year.	Rate of depreciation.	Amount.	Cost upto year.	Rate of depreciation.	Amount	Cost upto year.	Rate.	Amount.	
1	2	3	4	5	6	7	8	9	10	11
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
Fourth year ..	Installed only in the fourth year. Depreciation and maintenance cost is taken from fifth year, i.e. with a lag of one year									
Fifth year	1,50,00,000	1.66 per cent	2,49,000	2,95,50,000	2.75 per cent	8,12,625	4,45,50,000	1.5 per cent	6,63,250	17,29,875
Sixth year	3,00,00,000		4,98,000	4,95,50,000		13,62,625	7,95,50,000		11,93,250	30,53,875
Seventh year	4,50,00,000		7,47,000	4,95,50,000		13,62,625	21,98,50,000		32,97,750	54,07,375
Eighth year	6,00,00,000		9,96,000	6,05,00,000		16,63,750	24,58,00,000		36,27,000	62,86,750
Ninth year	6,00,00,000		9,96,000	6,55,00,000		18,01,250	25,08,00,000		37,62,000	65,59,250
Tenth year	6,00,00,000		9,96,000	6,55,00,000		18,01,250	25,08,00,000		37,62,000	65,59,250
Eleventh year	7,50,00,000		12,45,000	6,55,00,000		18,01,250	26,58,00,000		39,87,000	70,33,250
Twelfth year	7,50,00,000		12,45,000	6,55,00,000		18,01,250	26,58,00,000		39,87,000	70,33,250
Thirteenth year	9,00,00,000		14,94,000	6,55,00,000		18,01,250	28,08,00,000		42,12,000	75,07,250
Fourteenth year	9,00,00,000		14,94,000	6,55,00,000		18,01,250	28,08,00,000		42,12,000	75,07,250
Fifteenth year	9,00,00,000		14,94,000	6,55,00,000		18,01,250	28,08,00,000		42,12,000	75,07,250
Sixteenth year	10,50,00,000		17,43,000	6,55,00,000		18,01,250	29,58,00,000		44,37,000	79,81,250
Seventeenth year	10,50,00,000		17,43,000	6,55,00,000		18,01,250	29,58,00,000		44,37,000	79,81,250

PART VI.
Summary of Total Revenue.

Year	Net revenue from irrigation.	Net revenue from power.	Total net revenue Cols. 2+3.	Remarks.
1	2	3	4	5
Fourth year ..	2,68,501	12,40,000	15,48,501	
Fifth year ..	5,03,250	8,50,125	13,53,375	
Sixth year ..	6,82,351	4,46,125	11,28,476	
Seventh year ..	15,10,501	23,92,625	38,94,126	
Eighth year ..	18,49,000	86,73,250	1,03,22,250	
Ninth year ..	21,96,502	1,04,80,750	1,26,77,252	
Tenth year ..	23,70,250	1,08,40,750	1,32,11,000	
Eleventh year ..	25,44,001	1,29,76,750	1,55,20,751	
Twelfth year ..	27,17,751	1,18,66,750	1,45,84,501	
Thirteenth year ..	28,91,622	1,40,92,750	1,69,84,372	
Fourteenth year ..	30,65,249	1,67,92,750	1,98,57,999	
Fifteenth year ..	32,39,003	1,76,92,750	2,09,31,753	
Sixteenth year ..	32,39,003	1,90,18,750	2,22,57,753	
Seventeenth year ..	32,39,003	1,72,19,750	2,04,57,753	

Col. 2 is the same as col. 10 of Part IV c. Col. 3 is the same as col. 12 of Part V a.

PART VII. Estimate of Net Financial Results.

Year	Direct outlay during the year	Indirect outlay during the year	Total outlay during the year	Accumulative outlay upto end of year	Interest 3% (Simple)	Net Revenue	Simple interest less net revenue	Net revenue less simple interest
1	2	3	4	5	6	7	8	9
First year	1,28,64,605	1,00,000	1,29,64,605	1,29,64,605	1,94,469	..	1,94,469	..
Second year	6,27,60,930	6,06,000	6,33,66,930	7,63,31,535	13,39,442	..	13,39,442	..
Third year	10,00,72,260	10,64,000	10,11,36,260	17,74,67,795	38,06,990	..	38,06,990	..
Fourth year	9,70,32,135	8,65,000	9,78,97,135	27,53,64,930	67,92,491	15,48,501	52,43,990	..
Fifth year	8,67,21,725	7,10,000	8,74,31,725	36,27,96,655	95,72,424	13,53,375	82,19,049	..
Sixth year	4,56,75,345	2,58,000	4,59,33,345	40,87,30,000	1,15,72,900	11,23,476	1,04,44,424	..
Seventh year	1,94,70,000	..	1,94,70,000	42,82,00,000	1,25,53,950	38,94,126	86,59,824	..
Eighth year	5,00,000	..	5,00,000	42,87,00,000	1,28,53,500	1,05,22,250	23,31,250	..
Ninth year	5,00,000	..	5,00,000	42,92,00,000	1,31,08,500	1,26,77,252	4,31,248	..
Tenth year	1,55,00,000	..	1,55,00,000	44,47,00,000	1,33,48,500	1,32,11,000	1,37,500	..
Eleventh year	5,00,000	..	5,00,000	44,52,00,000	1,35,88,500	1,55,20,751	..	19,32,251
Twelfth year	1,55,00,000	..	1,55,00,000	46,07,00,000	1,38,28,500	1,45,84,501	..	7,56,001
Thirteenth year	5,00,000	..	5,00,000	46,12,00,000	1,38,51,000	1,69,84,372	..	31,33,372
Fourteenth year	10,00,000	..	10,00,000	46,22,00,000	1,41,04,500	1,98,57,999	..	57,53,496
Fifteenth year	1,59,00,000	..	1,59,00,000	47,81,00,000	1,45,81,500	2,09,31,753	..	62,50,253
Sixteenth year	..	..	..	47,81,00,000	1,43,43,000	2,22,57,753	..	79,14,753
Seventeenth year	..	..	..	47,81,00,000	1,43,43,000	2,04,57,753	..	61,14,753

Col. 2 is the same as col. 8 of Part II. Col. 3 is the same as Col. 4 of Part III. Col. 6 is the interest at 3% on the full amount of the outlay up to the previous year and half amount for the current year. Col. 7 is the same as Col. 4 of Part VI.

PART VIII. Estimated Financial Results.

Year	Cumulative capital outlay direct and indirect to year	Simple interest on direct outlay during the year	Cumulative interest to end of year	Net revenue during the year	Cumulative net revenue to end of year	Sum at charge at end of year	Percentage return of sum at charge	Remarks
1	2	3	4	5	6	7	8	9
First year	1,29,64,605	1,92,969	1,92,969	..	..	1,31,57,574	..	..
Second year	7,63,31,535	13,27,352	15,20,321	..	..	7,78,51,856	..	..
Third year	17,74,67,795	37,69,850	52,90,371	..	..	18,27,58,166	..	..
Fourth year	27,53,64,930	67,26,416	1,20,16,787	15,48,501	15,48,501	28,55,33,216	0.54	Power rate at Rs. 160 per k.w. (100,000 kw).
Fifth year	36,27,96,655	94,82,724	2,14,99,511	13,53,375	29,01,876	38,13,94,290	0.37	..
Sixth year	40,87,30,000	1,14,68,680	3,29,68,191	11,28,476	40,30,352	43,76,67,839	0.24	..
Seventh year	42,82,00,000	1,24,45,860	4,54,14,051	38,94,126	79,24,478	46,46,89,573	0.84	..
Eighth year	42,87,00,000	1,27,45,410	5,81,59,461	1,05,22,250	1,84,46,728	46,84,12,733	2.16	..
Ninth year	42,92,00,000	1,27,60,410	7,09,19,871	1,26,77,252	3,11,23,980	46,89,95,891	2.70	Power rate reduced from Rs. 160 to Rs. 150 per k.w. (150,000 kw.)
Tenth year	44,47,00,000	1,30,00,410	8,39,20,281	1,32,11,000	4,43,34,980	48,42,85,301	2.74	..
Eleventh year	44,52,00,000	1,32,40,410	9,71,60,691	1,55,20,751	5,98,55,731	48,25,04,960	3.22	..
Twelfth year	46,07,00,000	1,34,80,410	11,06,41,101	1,45,84,501	7,44,40,232	49,69,00,869	2.91	Power rate reduced from Rs. 150 to Rs. 121 (200,000 kw).
Thirteenth yr.	46,12,00,000	1,37,20,410	12,43,61,511	1,69,94,372	9,14,24,604	49,41,36,907	3.42	..
Fourteenth yr.	46,22,00,000	1,37,42,910	13,81,04,421	1,98,57,999	11,12,82,603	48,90,21,818	4.06	..
Fifteenth yr.	47,81,00,000	1,39,96,410	15,21,00,831	2,09,31,753	13,22,14,356	49,79,86,473	4.29	..
Sixteenth yr.	47,81,00,000	1,42,34,910	16,63,35,741	2,22,57,753	15,44,72,109	48,99,03,632	4.51	..
Seventeenth yr.	47,81,00,000	1,42,34,910	18,05,70,651	2,04,57,753	17,49,29,862	48,37,40,789	4.23	Power rate reduced from Rs. 120 to Rs. 100. (350,000 kw).
Eighteenth yr.	47,81,00,000	1,42,34,910	19,48,05,561	2,04,57,753	19,52,87,615	47,75,17,946	4.29	..

Col. 2 is the same as Col. 4 of Part VII. Col. 3 is the interest at 3% on the direct outlay for the full amount up to the previous year and half the amount for the current year.

Col. 5 is the same as col. 2 of part VI. Col. 7 is col. 2 + col. 4—col. 6. Col. 8 is percentage of col. 5 on col. 7.

ACKNOWLEDGEMENTS.

The preliminary investigations on the unified development of the Mahanadi Valley were taken in hand soon after the Cuttack Conference of the 8th November 1945, but real activity, particularly on the Hirakud dam project, did not start until late in May 1946. Mr. R. P. Vasishth, I.S.E., Superintending Engineer, has throughout been the Project Officer in-charge of these operations. It is mainly due to his great administrative skill, technical ability, initiative and drive that it has been possible to complete the field work and produce a project report in so short a time. In this task he had the loyal and able co-operation of Messrs. M. B. Rangaswamy, Assistant Director and S. K. Palit, Executive Engineer, and of the many officers, supervisors, draftsmen and clerical staff under them. Mr. Rangaswamy did most commendable work in the preparation of the project report. The work of Dr. R. C. Hoon, PH.D., in connection with the soil surveys of the areas to be irrigated and those set apart for the re-settlement of the dispossessed people, deserves special mention. Lt.-Col. T. M. Oag, Director of Navigation has written a valuable note on the navigation possibilities of the Mahanadi river. Mr. J. Bannerji, I.F.S., has submitted a useful report on the forest aspect of the project. Mr. P. S. Shinghal, Assistant Director, did much useful work in the preparation and printing of maps and drawings. Messrs. Bhim Sen and M. P. B. Nair, Personal Assistants to the Chairman, did good work in the preparation of the report.

Acknowledgements are due to the Surveyor Generals of India, Brigadier Sir E. Oliver Wheeler, M.C., and Brigadier G. F. Heaney, C.B.E., Deputy Surveyor Generals, Col. J. B. P. Angwin, M.B.E., R.E., and Col. C. A. K. Wilson, M.B.E., R.E., the Director of Map Publications, Major H. W. Wright, O.B.E., R.E., and the Director of Eastern Circle Major R. T. L. Rogers, R.E., for the promptness and efficiency with which they have carried out the aerial and ground surveys for the project and the preparation and printing of the survey maps. Without their co-operation the work of the project would have been very materially delayed.

Acknowledgements are also due to the Director of the Geological Survey of India Dr. W. D. West, Superintending Geologists Messrs. J. B. Auden and V. P. Sondhi and Geologists Messrs. A. G. Jhingran, K. K. Dutta and in particular Mr. V. S. Krishnaswamy (who has done most of the field work), for their whole-hearted co-operation in connection with the geological investigations of the dam sites, reservoir area and mineral deposits. In these geological investigations we had the benefit of the advice of Dr. F. A. Nickell, Consulting Geologist, U.S.A., whose services were specially requisitioned for the purpose.

The dam sites were visited and the preliminary report, in so far as it was ready, was reviewed by Dr. J. L. Savage, Consulting Engineer and world expert in the design of dams. His report, which is at Appendix XVI, is of the utmost value.

Thanks are due to the many officers of the Orissa Government whose valuable assistance and advice have contributed to the usefulness of the project report. Mr. R. L. Narayanan, Chief Engineer Electricity, has been closely associated with the preparation of the hydro-electrical part of the project and Mr. M. L. Narasimhaiengar, Director of Industries with that of industrial development. Khan Bahadur A. Karim, Chief Engineer, Irrigation and Mr. J. Shaw, Superintending Engineer have given valuable assistance and

information whenever asked. Mr. R. S. Swann, I.C.S., Deputy Commissioner, Sambalpur has given a valuable note in respect of compensation for lands and the question of resettlement of dispossessed people. The work of Bawa Sewa Singh, Superintendent, Consulting Engineer's Branch, in collecting statistics of areas, land values, etc., deserves special mention. Rai Sahib Jagannath Misra, Additional District Magistrate, Hirakud, gave valuable assistance in the preparation of the note by Mr. Swann and in collecting all local information and statistics. Rai Sahib M. N. Pradhan, Agricultural Officer was of great assistance in the work of soil surveys.

Acknowledgements are due to Mr. P. G. Bhagat, M.B.E., Controller of Printing, Mr. M. K. Majumdar, Manager, Government of India Press, Simla and Mr. A. C. Das Gupta, Assistant Manager for the printing of the project report under difficult conditions. The Library of the Central Board of Irrigation has been of the utmost assistance in supplying useful information. The Department of Information and Broadcasting kindly lent their artist to produce the Artist's conception of the "Hirakud Dam" and of "The Sambalpur of Tomorrow".

In conclusion I would like to record my deep sense of gratitude for the unfailing support and valuable guidance which I have received in the preparation of this project from the Hon'ble Dr. B. R. Ambedkar, the Hon'ble Sir M. S. Akbar Hydari, K.C.S.I., G.S.I., I.C.S., the Hon'ble Sjt. Sarat Chandra Bose, the Hon'ble Mr. C. H. Bhabha, successive Members for Labour, and Works, Mines and Power and the Secretaries Sir H. C. Prior, C.S.I., C.I.E., I.C.S., and in particular, Mr. B. K. Gokhale, C.S.I., C.I.E., I.C.S. ~~and~~ Mr. Gokhale's special knowledge of the conditions in Orissa Province and his great sympathy for her people contributed greatly to the early and satisfactory preparation of the project work.

I am also grateful to the Finance Department of the Government of India, and its Secretary The Hon'ble Mr. V. Narahari Rao, C.S.I., whose prompt and sympathetic consideration, of all reasonable proposals put forward in respect of the project, was largely responsible for the rapid and uninterrupted progress made by C.W.I.N.C., on surveys and investigations.

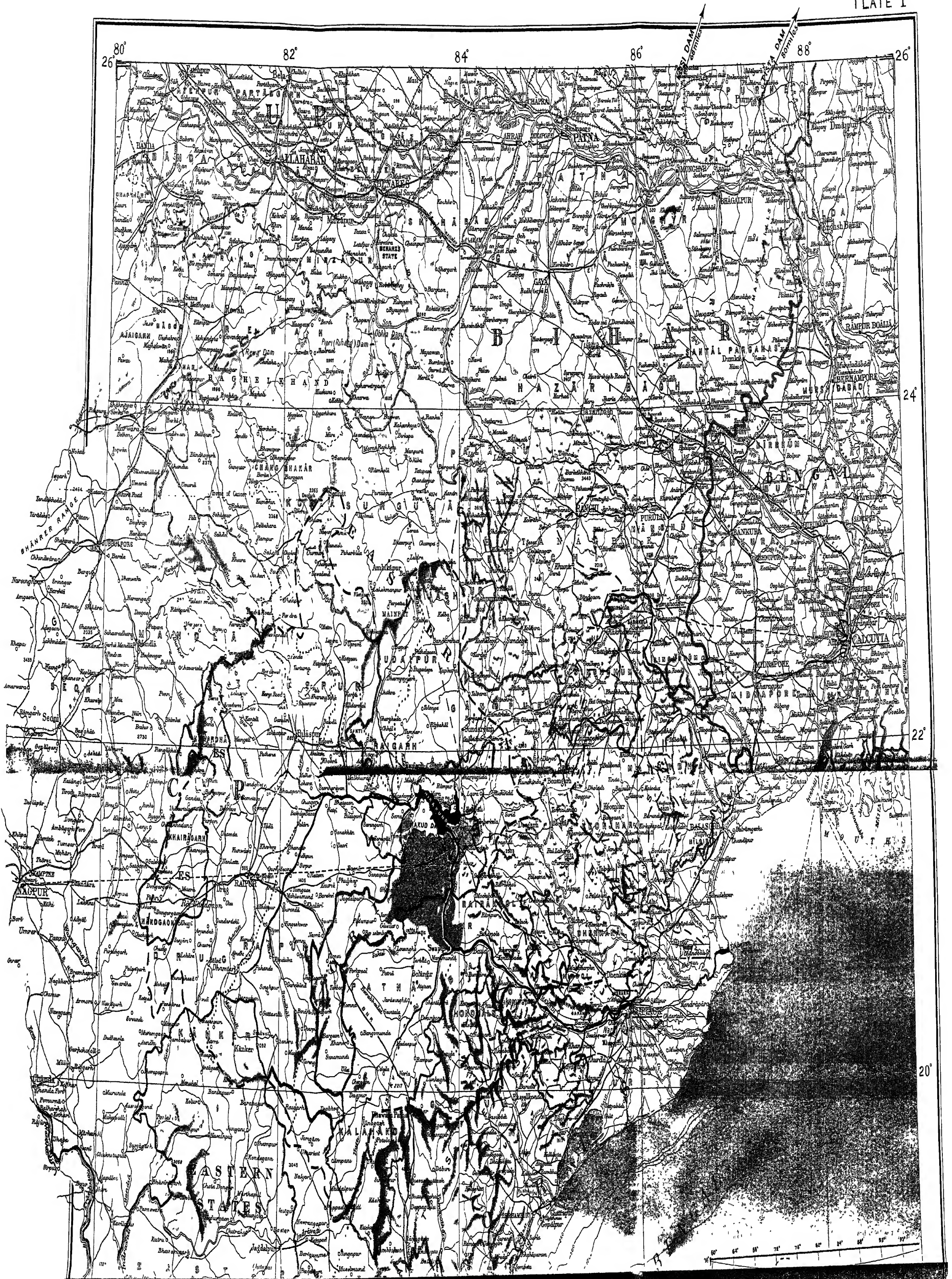
To His Excellency Sir C. M. Trivedi, K.C.S.I., C.I.E., O.B.E., I.C.S., the Governor of Orissa and the Hon'ble Sri H. K. Mahatab, the Prime Minister, my officers and I owe a deep debt of gratitude for the kindness, courtesy, encouragement and assistance, which we have received in the discharge of our duties in connection with the Hirakud dam project.

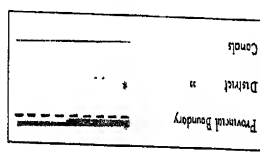
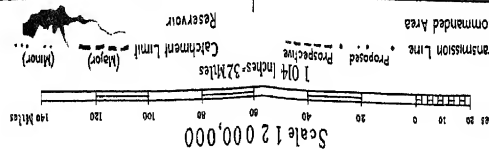
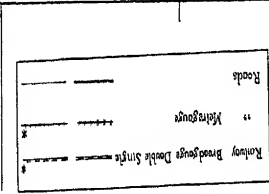
A. N. KHOSLA, I.S.E.,

Chairman,

Central Waterways, Irrigation

and Navigation Commission.



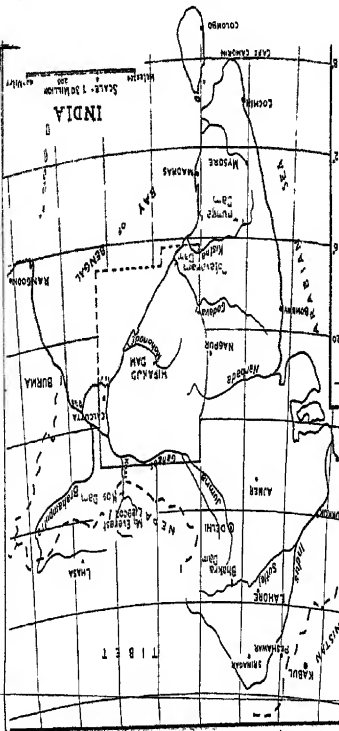


HIRAKUD DAM PROJECT

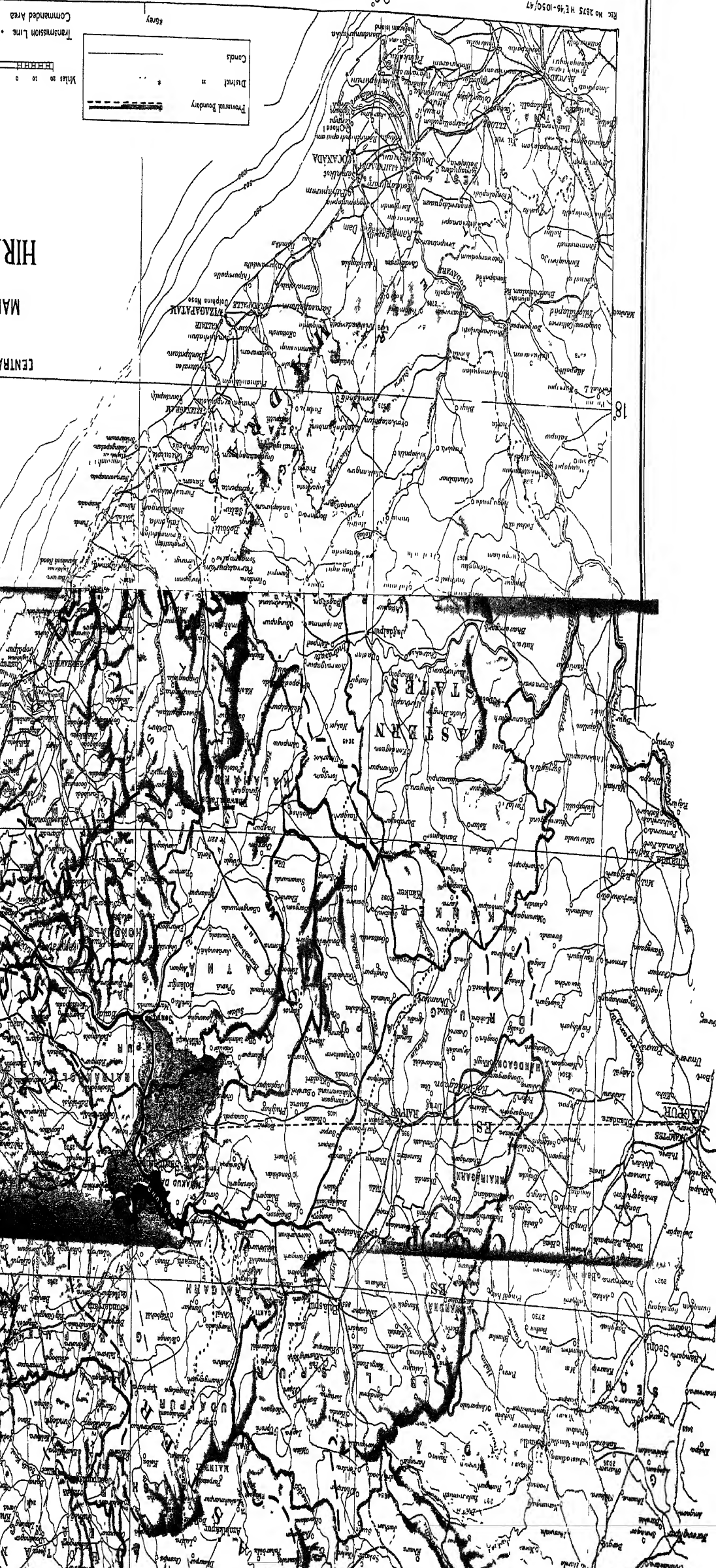
MAHANADI VALLEY DEVELOPMENT

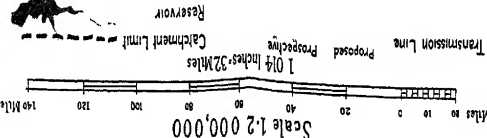
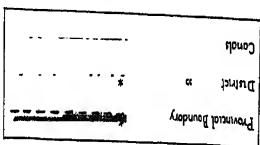
CENTRAL WATERWAYS, IRRIGATION & NAVIGATION COMMISSION

SHOWING PROJECT FEATURES

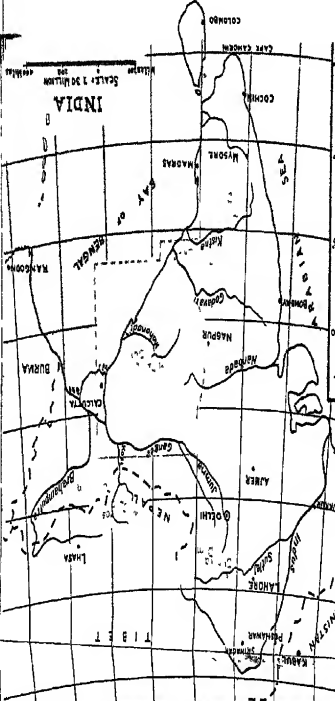


BAY OF BENGAL



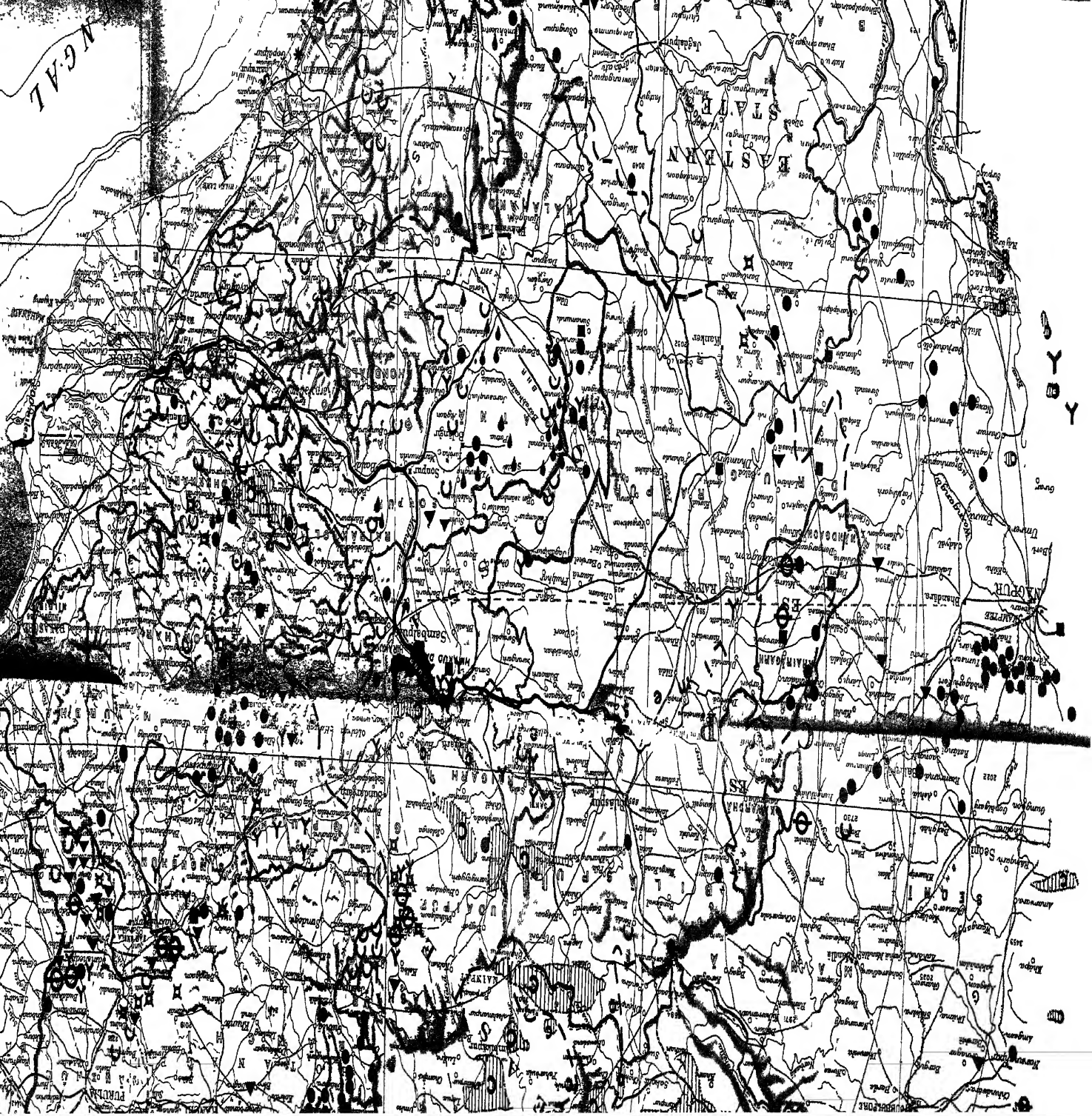


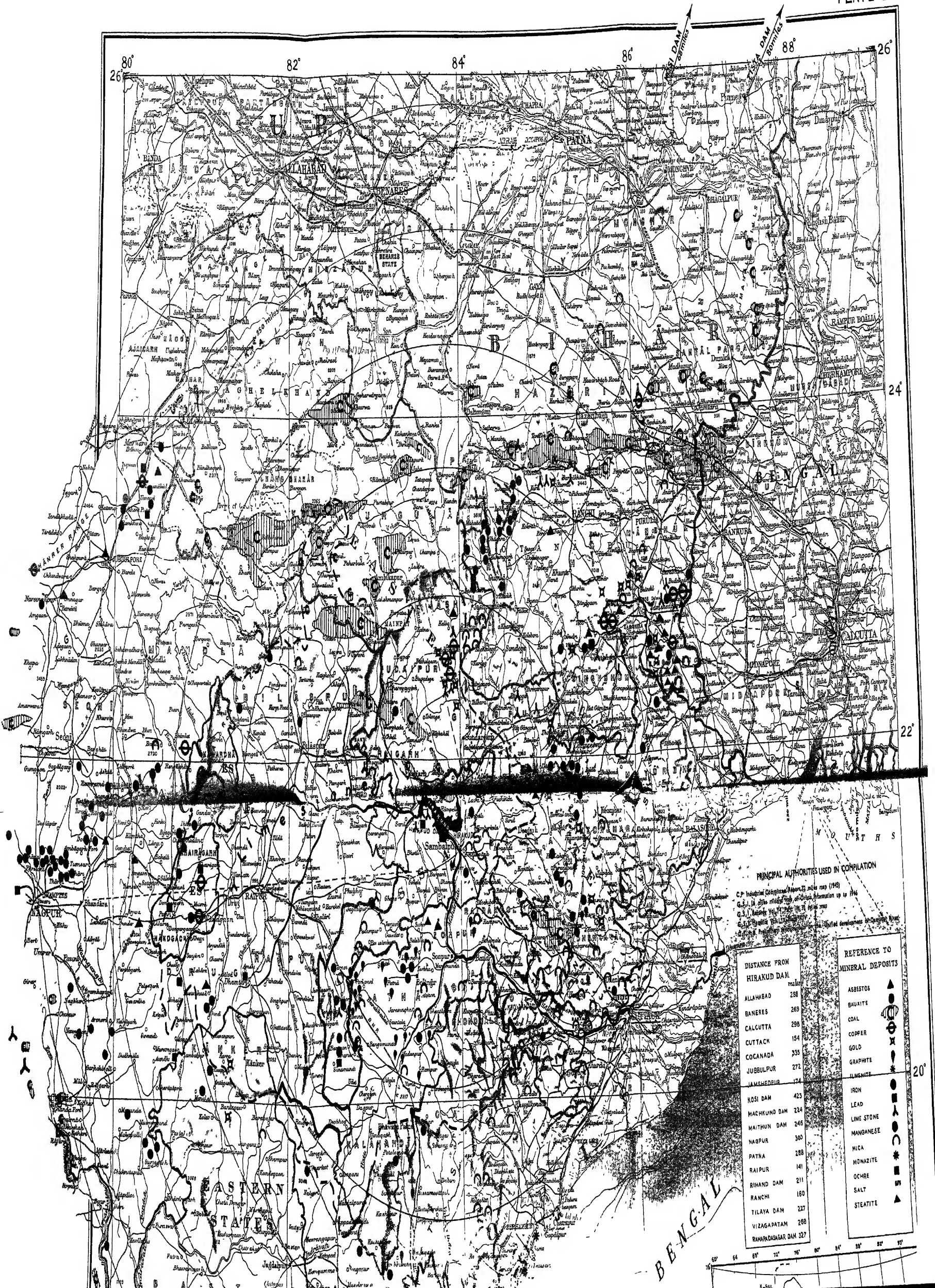
HIRAKUD DAM PROJECT MAHANADI VALLEY DEVELOPMENT COMMISSION INDEX MAP SHOWING MINERAL DEPOSITS



REFERENCE TO	MINERAL DEPOSITS
▲	STEATITE
■	SALT
◆	OPHRE
●	MONAZITE
○	MICA
●	MANGANESE
●	LIME STONE
●	LEAD
●	IRON
●	LIQUORITE
●	GOLD
●	COPPER
●	COAL
●	BAUXITE
●	ASBESTOS

DISTANCE FROM	HIRAKUD DAM
ALMABAD	298
BANERES	269
CALCUTTA	298
CUTTACK	154
COCANADA	235
JUBBILPUR	272
JAMSHEDPUR	174
KOL DAM	423
MACHHUND DAM	224
MATHUR DAM	246
NAGPUR	300
PATNA	288
RAIPUR	141
RINAND DAM	211
RANCHI	180
TILAY DAM	227
VIZAGAPATAM	268
RAMANAGAR DAM	227





CENTRAL WATERWAYS, IRRIGATION & NAVIGATION
COMMISSION

MAHANADI VALLEY DEVELOPMENT

HIRAKUD DAM PROJECT

INDEX MAP

SHOWING PROJECT FEATURES

CENTRAL PROVINCES & BERAR
EASTERN STATES, ORISSA

Index to 1/4 inch Sheet

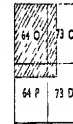
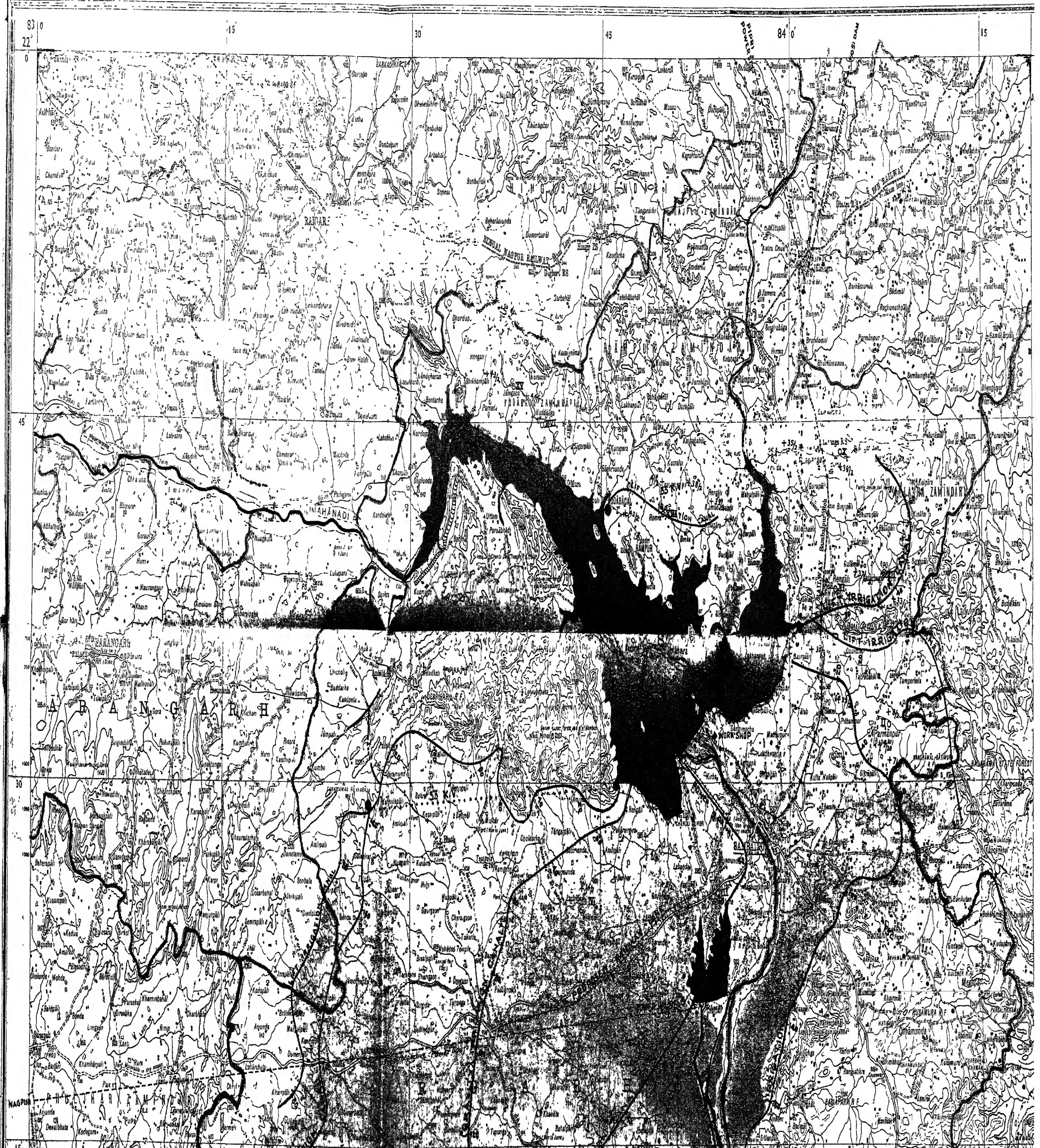
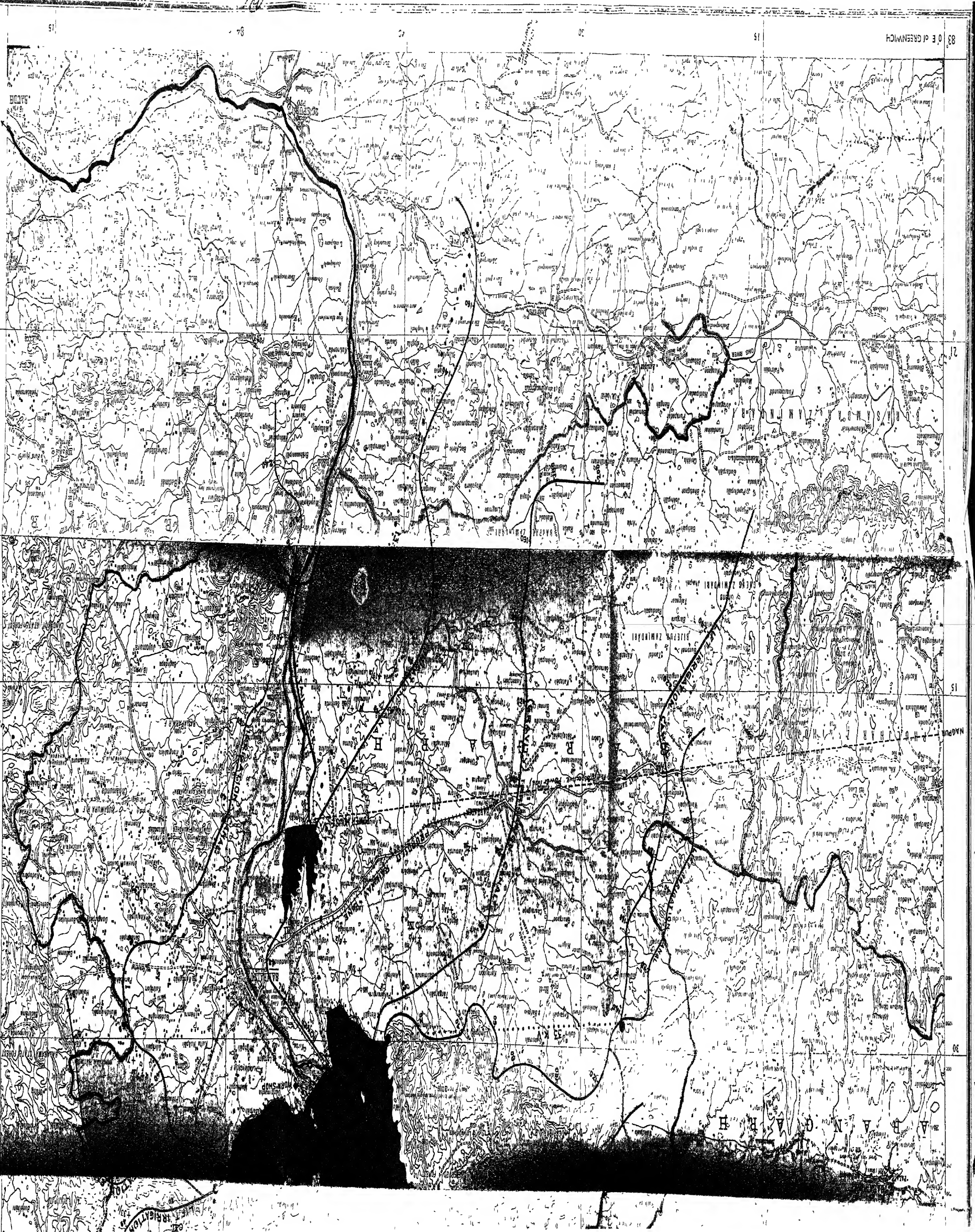


PLATE III

Sheet 64 O

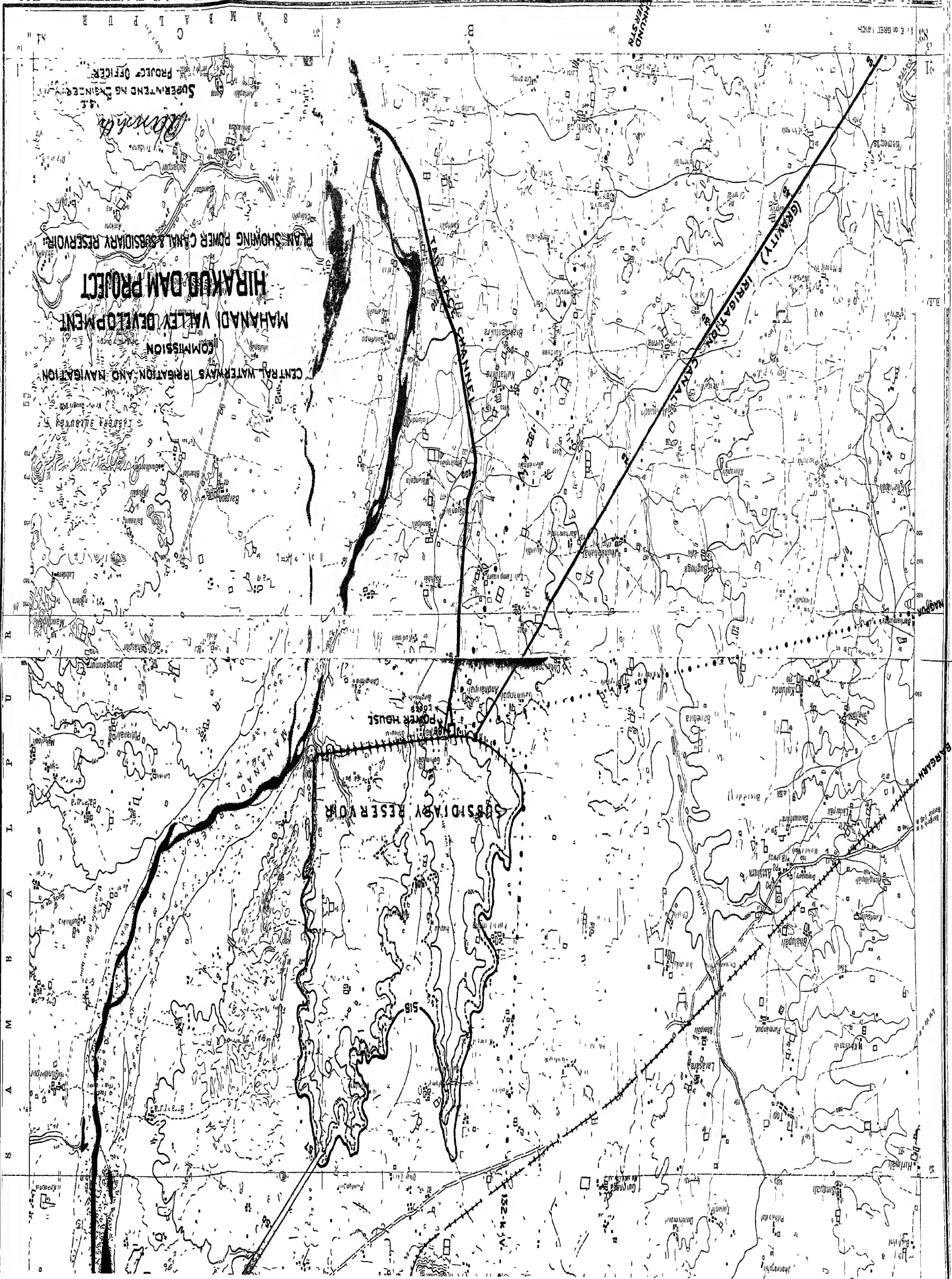
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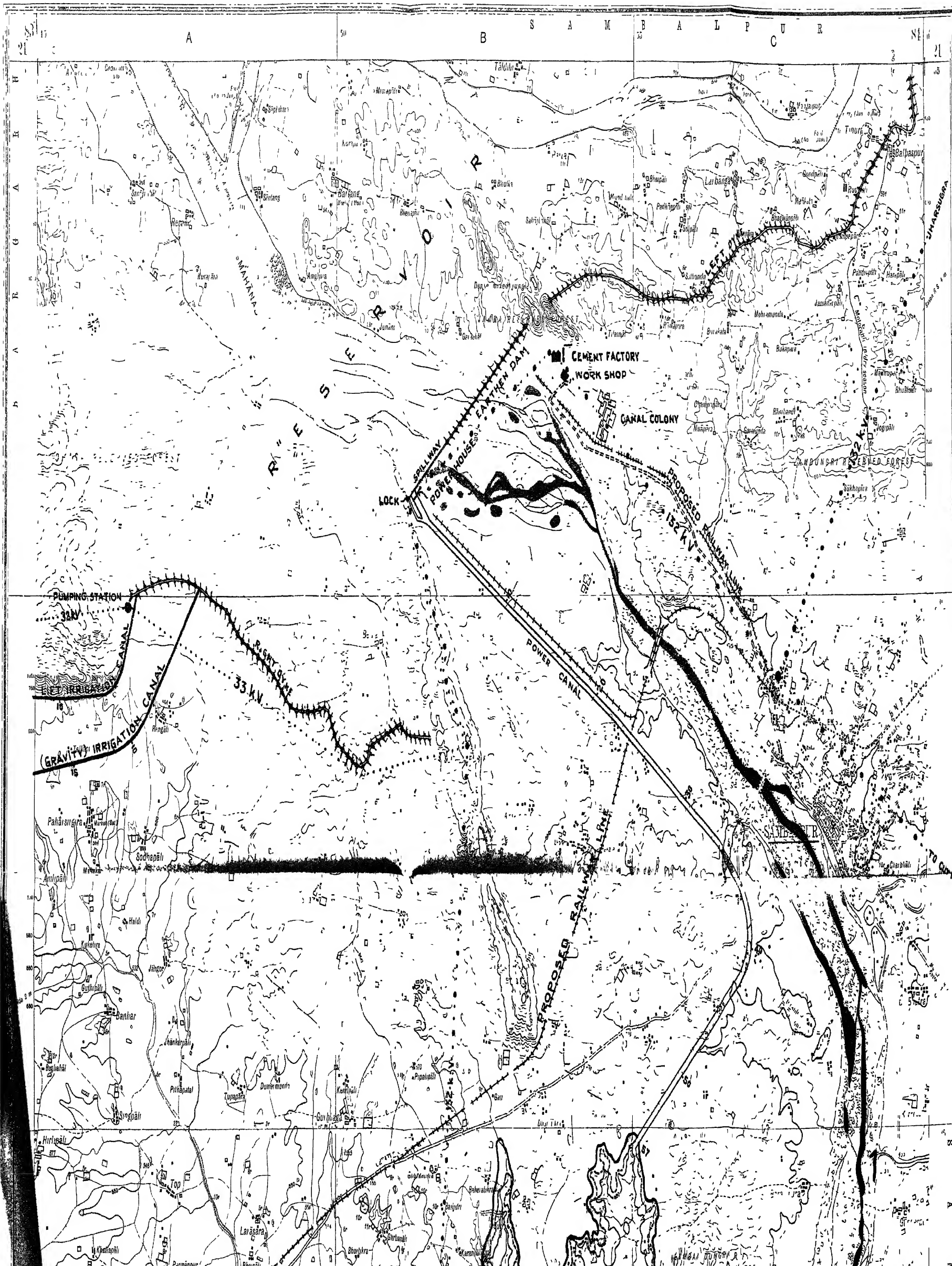
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Based upon survey of 1935-36 with an extension to the Survey General of India



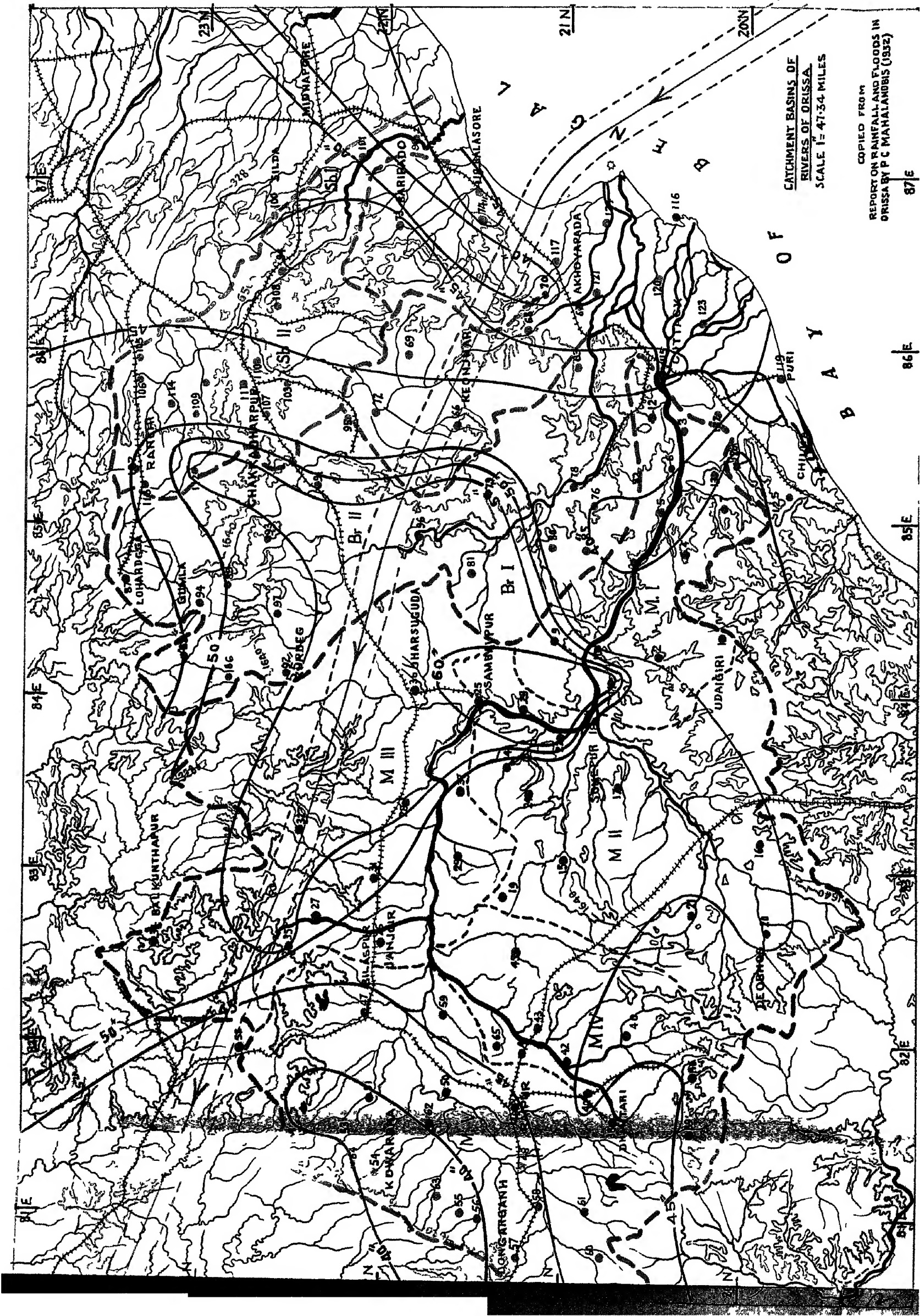
MAHANADI VALLEY DEVELOPMENT
HIRAKUD DAM PROJECT
POWER CANAL & SUBSIDIARY RESERVOIR
COMMISSION
CENTRAL WATERWAYS IRRIGATION AND NAVIGATION
PROJECT OFFICER
SUPERINTENDING ENGINEER

SUBSIDIARY RESERVOIR
POWER HOUSE



REFERENCES
TO
SAMBALPUR TOWN

- 1 *Agricultural Farm*
- 2 *Bara Bāzār*
- 3 *Chhūwapāra*
- 4 *Circuit House*
- 5 *Civil Hospital*
- 6 *Club*
- 7 *Dāk Bungalow (PWD)*
- 8 *District Courts*
- 9 *District Jail*
- 10 *Forest Offices*
- ~~11 *Government Offices*~~
- 12 *Magnetic Station*
- 13 *Manikmunda*
- 14 *Market (Sun)*
- 15 *Meteorological Observatory*
- 16 *Municipal Offices*
- 17 *Police Hospital*
- 18 *Police Lines*
- 19 *Police Station*
- 20 *Post and Telegraph Office*
- 21 *PWD Offices*
- 22 *Sidhesaberna*
- 23 *Veterinary Dispensary*

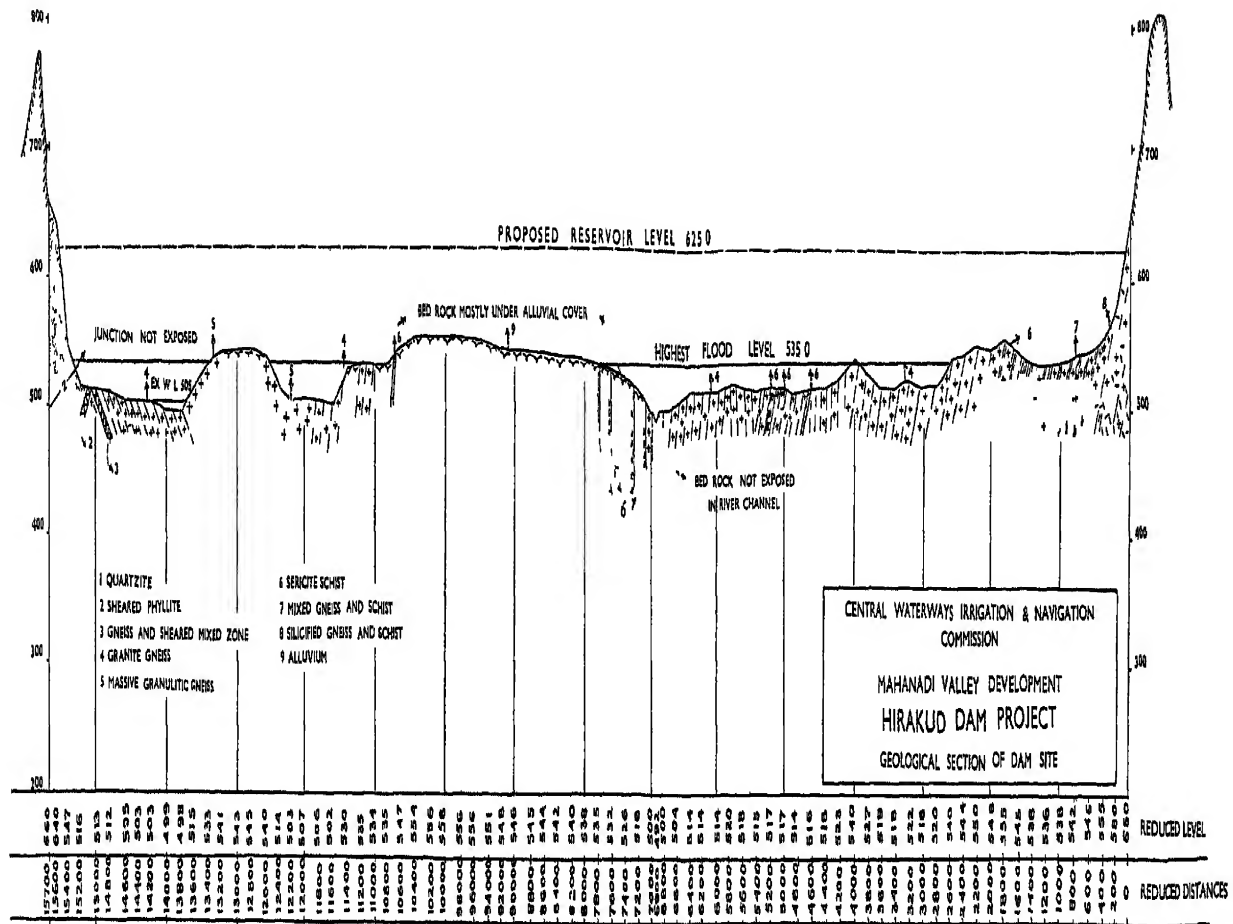


CATCHMENT BASINS OF
RIVERS OF ORISSA
SCALE 1" = 47.34 MILES

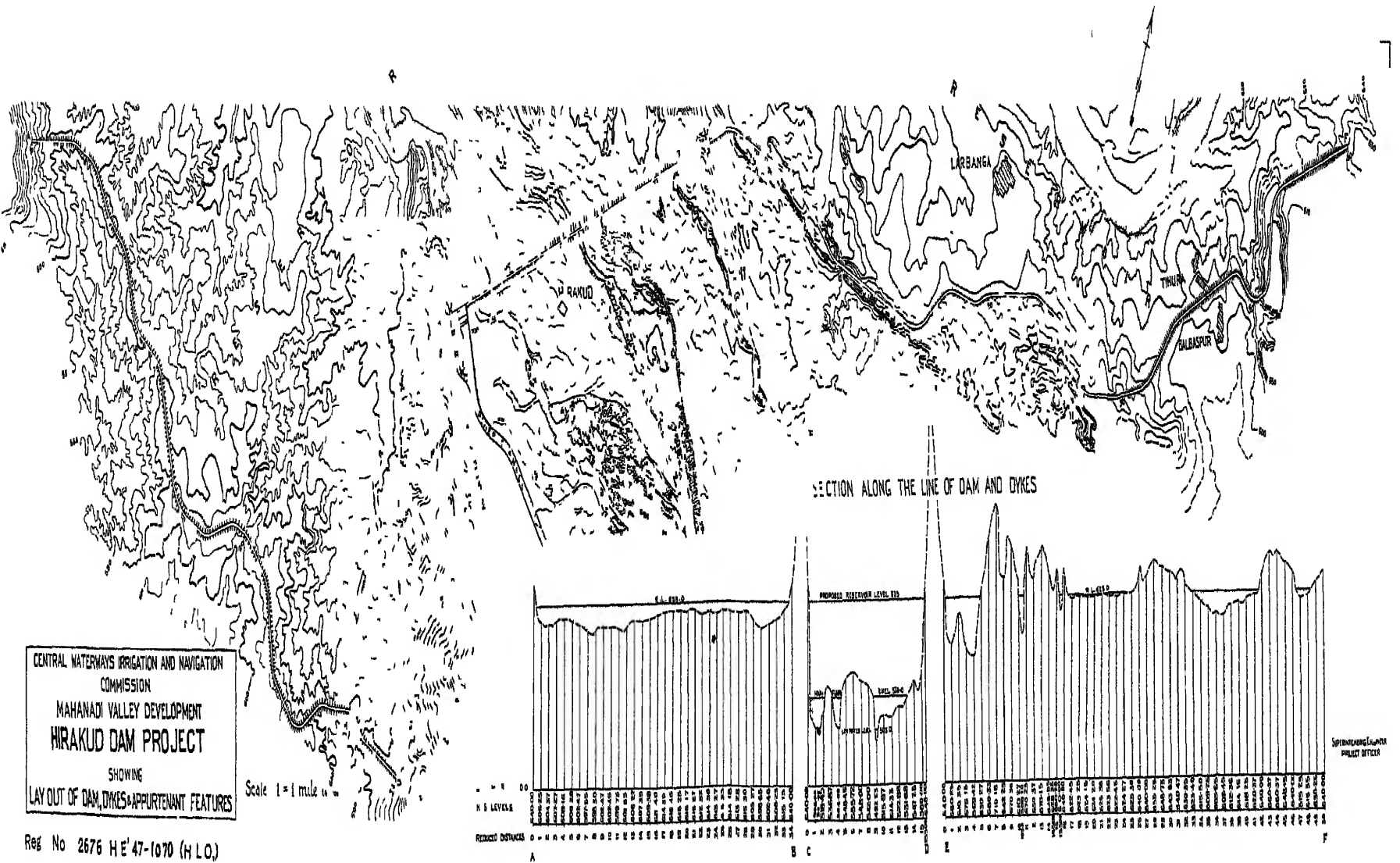
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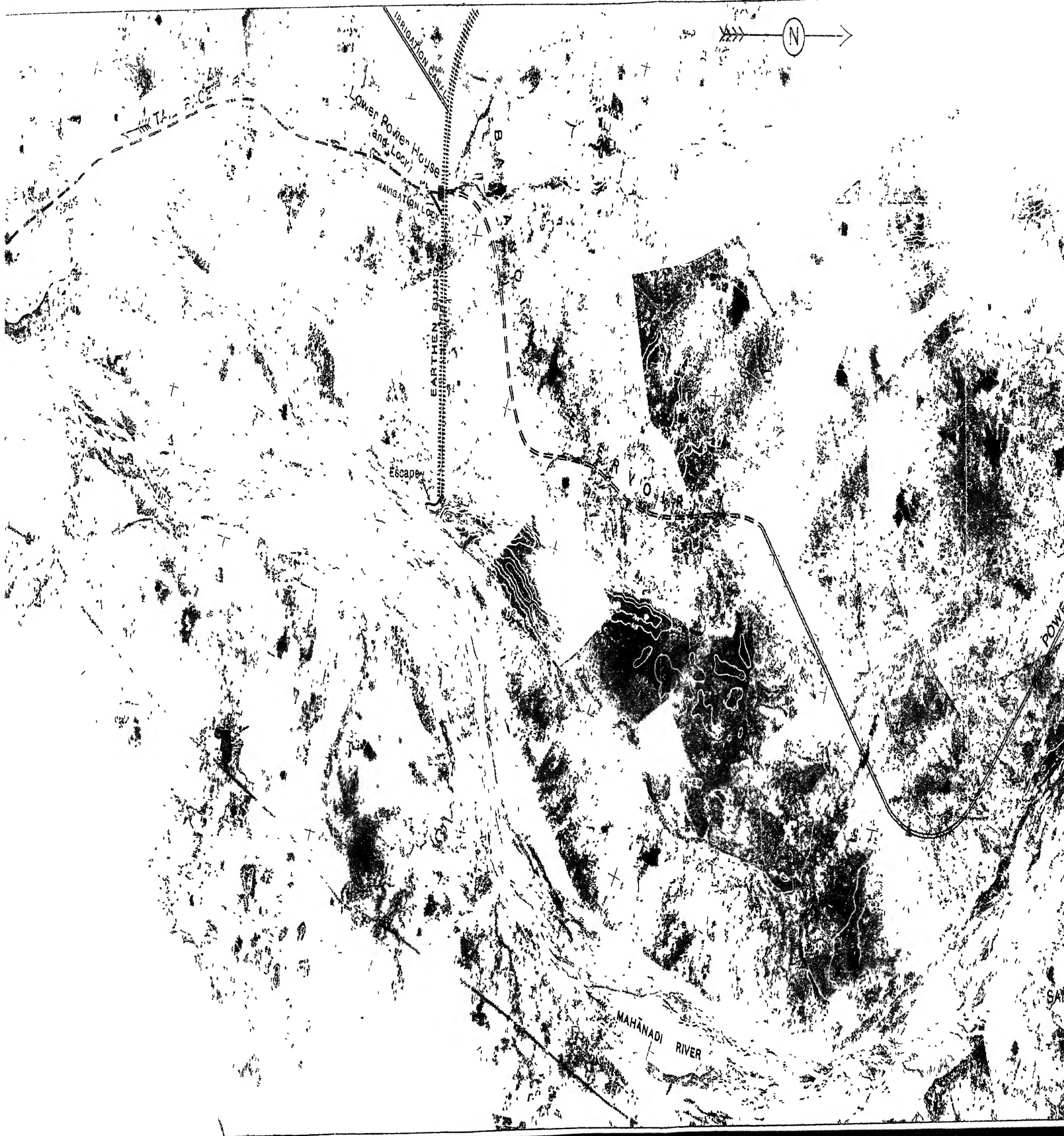
ANNUAL AND MONSOON RAINFALL

Serial No	Name of Station	ANNUAL Normal	MONSOON		Serial No	Name of Station	ANNUAL Normal	MONSOON	
			Actual	p c				Actual	p c
Mahanadi I					Bastarani				
1	Udaigiri ..	54 45	40 46	74 3	66	Keonjhar	47 98	36 47	76 0
2	Phulbani	52 58	43 88	83 5	67	Akhoyapada	58 23	42 83	73 6
3	Banki	52 82	42 25	80 0	68	Anandpur	54 86	40 02	72 9
4	Kunjabangarh ..	51 27	41 25	80 1	69	Karanja	61 14	46 70	76 4
5	Narsinghpur	48 38	39 27	81 2	70	Bonth	54 13	38 55	71 2
6	Baramba ..	53 01	42 30	79 8	71	Korai	52 15	39 50	75 7
7	Nayagarh ...	51 89	41 23	73 5	72	Champua			
8	Tikerpara	47 59	38 90	81 7	Nilgiri				
9	Rampur	60 93	54 14	88 9	73	Baripado	62 93	46 74	74 3
10	Band	51 23	43 76	85 4	74	Nilgi 1	68 15	46 18	67 8
11	Balandapara	73 74	64 33	87 2	75	Turigaria	60 20	42 29	70 2
12	Athgaih	53 71	63 11	80 3	Brahmani I				
13	Bolgaih	53 89	39 26	72 9	76	Angul	48 92	37 63	76 9
Mahanadi II					77	Dhenkanal	57 58	44 77	77 8
14	Bargarh	53 67	47 86	89 2	78	Talcher	51 61	41 24	79 9
15	Padampur	52 7	44 98	85 6	79	Pal Lahera	67 98	56 76	83 5
16	Bhowanipatna ...	57 65	48 68	84 4	80	Chhendipara	51 10	4 35	80 9
17	Bolangir ...	56 45	48 06	85 1	81	Deogarh	67 29	57 10	84 9
18	Sonepur	55 10	48 25	87 6	82	Hindol	55 26	41 77	75 6
19	Saraipali	53 63	47 21	88 0	83	Sukinda	65 08	47 31	72 6
20	Deobhog	53 84	45 01	83 6	84	Barchana	64 66	47 04	72 7
21	Khariar ...	53 37	43 88	82 4	85	Jarpara			
22	Binka	71 56	61 97	86 6	Brahmani II				
23	Dhamka				86	Jashpur	65 00	54 38	83 7
24	Bijepur				87	Lohardaga	51 36	42 20	82 2
Mahanadi III					88	Champur	54 46	44 67	82 0
25	Sambalpur	70 22	63 38	90 3	89	Palkot	59 68	50 09	83 9
26	Janjgir ...	51 9	46 01	89 4	90	Gailkura	61 12	50 44	8 5
27	Korba	57 10	50 47	88 4	91	Monoharpur	61 2	51 51	83 9
28	Rajgarh	62 23	56 5	90 7	92	Kurdeg	6 36	53 35	88 4
29	Sarangarh	53 24	47 03	88 4	93	Bano	59 11	51 16	86 6
30	Gangpur	61 57	53 35	86 6	94	Gumla	54 22	44 12	81 4
31	Sakti ...	60 64	54 00	89 1	95	Jagannathpur	53 77	43 39	80 7
32	Dharmajaigarh	64 94	57 32	88 3	96	Borsigarh	66 31	57 14	86 2
33	Pasan	48 10	42 04	87 4	97	Simdega			
34	Baikunthapur	61 15	52 71	85 8	Subarnarekha I				
35	Katghora	64 51	56 06	86 9	98	Jellascre	58 78	43 43	73 9
36	Jharsuguda				99	Bharogora	57 38	44 40	77 4
37	Ambhabhona				100	Silda	56 18	41 07	73 1
Mahanadi IV					101	Kultikri	56 28	39 27	69 8
38	Dhamtari	50 72	45 13	89 0	Subarnarekha II				
39	Kankar	51 28	42 96	83 8	102	Ranchi	54 72	45 30	82 8
40	Ganabund	57 45	49 27	85 8	103	Chaibassi	52 95	41 83	79 0
41	Arang	55 21	48 86	88 5	104	Ghatsila	57 56	4 63	79 3
42	Rajm	56 04	48 78	87 0	105	Jhalda	54 98	4 82	81 5
43	Mahesamund	62 85	55 43	88 2	106	Silli	5 38	42 78	83 3
44	Kurid	48 91	43 63	89 2	107	Chakradharpur	5 99	41 91	80 6
45	Pithora				108	Kalikapur	62 34	40 77	79 8
46	Nowpara				109	Tamar	51 07	42 36	82 9
Mahanadi V					110	Seraikella	49 54	38 90	78 5
47	Bilaspur	49 63	43 36	87 4	111	Kharswan	56 07	45 12	80 5
48	Drug	48 23	42 80	88 7	112	Khunti	66 58	55 59	83 5
49	Raipur	50 3	44 42	88 1	113	Piska			
50	Simga	44 64	40 22	90 1	114	Sonahatu			
51	Mungeli	45 33	39 65	87 5	Delta				
52	Pendra	51 58	43 43	84 2	115	Cuttack	60 66	45 93	75 7
53	Pendaria	43 65	36 77	84 2	116	Hukitola	65 26	44 80	68 6
54	Kowaidha	40 72	32 90	80 8	117	Bhad ak	60 14	42 86	71 3
55	Chhuikhadan	42 79	35 25	82 4	118	Balasore	63 82	45 20	70 8
56	Khairagaih	45 70	38 14	83 5	119	Puri	53 99	37 89	70 2
57	Dongargarh	50 85	43 09	84 7	120	Kendrapara	59 7	43 22	72 7
58	Nandagaon	52 39	44 07	84 1	121	Jaipur	59 90	43 98	73 4
59	Boladabazar	53 89	46 72	88 3	122	Khurda	59 29	44 91	75 7
60	Ambachowki	55 25	47 99	86 9	123	Jagalsingpur	60 71	44 35	73 1
61	Sanjari	53 21	45 33	85 2	124	Chandbally	60 98	42 96	7 4
62	Bemetara	47 79	41 66	87 2	125	Banpur	53 33	39 07	72 6
63	Gondai	42 60	35 82	84 1	126	Rampur	57 06	42 62	74 7
64	Pondi Lafa	57 55	51 43	89 4					
65	Kusrangi	51 25	45 85	89 5					



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Ref No 2554 H.E. of 1971







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